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Evaluation of the Refuse Management Systems of Operation Breakthrough Sites

Hittman Associates, Inc, Columbia, Md

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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One of the provisions of the Operation Breakthrough program in the Department of Housing and Urban Development, Office of Policy Development and Research, is to evaluate the refuse management systems to determine economic and technical practicality for application to future projects. The nine sites are Indianapolis, Kalamazoo, Macon, Memphis, St. Louis, Seattle, Sacramento, King County, and Jersey City. The evaluations show that the methods employed at the Macon, Memphis, Sacramento, and King County sites are the most economical and effective.

The Jersey City site utilizes pneumatic trash collection and a separate report is being prepared to assess the technical and economic performance of the system.

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EVALUATION OF THE REFUSE MANAGEMENT SYSTEMS OF OPERATION BREAKTHROUGH SITES

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Contract No. 68-03-0094

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ABSTRACT

One of the provisions of the Operation Breakthrough program in the Department of Housing and Urban Development, Office of Policy Development and Research, is to evaluate the refuse management systems to determine economic and technical practicality for application to future projects. The nine sites are Indianapolis, Kalamazoo, Macon, Memphis, St. Louis, Seattle, Sacramento, King County, and Jersey City. The evaluations show that the methods employed at the Macon, Memphis, Sacramento, and King County sites are the most economical and effective. The five very conventional systems consist of central containers at Macon, Memphis, and Seattle and primarily curbside collection at King County. The Indianapolis site uses storage pens which results in low costs but also results in odors, insects, and refuse scattering. The central or communal compactors at Kalamazoo are not effective or economical because of improper utilization by residents. The St. Louis system desperately needs modifying because it is extremely costly and very ineffective. The Jersey City site utilizes pneumatic trash collection and a separate report is being prepared to assess the technical and economic performance of the system. In addition, a refuse system user acceptance survey was conducted at each site, and the results are documented in separate reports for each site with an executive summary for all sites.

Recommendations for refuse management systems in future projects are based on the results of the study. It is also recommended that the St. Louis site be studied and modified to reduce costs, increase system effectiveness and efficiency, and reduce environmental problems.

This report is submitted in partial fulfillment of Contract Number 68-03-0094 by Hittman Associates, Inc. The work was performed for the Environmental Protection Agency and was sponsored by the Office of Policy Development and Research, Division of Energy, Building Technology, and Standards, Department of Housing and Urban Development.

TABLE OF CONTENTS

Page

Abstract iii

List of Figures v

List of Tables x

Acknowledgements xiv

Glossary of Abbreviations xv

Sections

I Introduction 1

II Conclusions 7

III Recommendations 15

IV Data Collection and Analysis 21

Indianapolis, Indiana 21
Kalamazoo, Michigan 34
Macon, Georgia 50
Memphis, Tennessee 67
St. Louis, Missouri 80
Seattle, Washington 101
Sacramento, California 111
King County, Washington 124
King County Plastic Bag Study 136

References 151

FIGURES

No.		Page
1	Typical of 24 refuse storage pens at the Indianapolis Operation Breakthrough site. Only plastic bags are allowed and are collected by the municipal refuse service	22
2	Trash chute base and container in MFLR building at the Indianapolis site. Note the right angle feed to the container which results in daily chute blockages	23
3	Typical of two standard 4 cu yd containers at the Indianapolis Operation Breakthrough site	23
4	Indianapolis Operation Breakthrough site arrangement of pens and containers	24
5	Typical of sixteen compactors in covered pens located around Kalamazoo, Michigan site	36
6	On-site refuse collection at Kalamazoo, Michigan.	37
7	Refuse storage in 4-cu yd containers and collection by a top-loading packer truck at Kalamazoo, Michigan	38
8	Kalamazoo Operation Breakthrough site arrangement showing location of compactors	39
9	Two typical containers and pen locations at the Macon site. One is center left next to the trees. The other is just to the right of the basketball goal	52
10	The chute-fed compactor and container in the MFM/HR building at the Macon site	52
11	Macon Operation Breakthrough site arrangement of containers	53

FIGURES (Continued)

No.		Page
12	One compactor container is replaced with empty between service days at the MFM/HR at the Macon site	55
13	Private contractor top-loading packer truck used to empty containers at the Macon site	55
14	MFM/HR refuse chute with off-set compactor and restricted opening at the chute-to-chamber interface which results in chute backups	61
15	Refuse chute blockage at second floor of MFM/HR building at the Macon site. Chute was backed up to third floor	62
16	Refuse spills out of side opening of compactor containers in the MFM/HR building on the Macon site	63
17	Typical 3-cu yd container and concrete pen installation at the Memphis site	68
18	Compactor with container attached in one of the MFHR buildings on the Memphis site	68
19	Ramp to compactor room in the MFHR building on the Memphis site	69
20	Typical 31-cu yd packer truck as used for collecting refuse from containers at the Memphis site	69
21	Memphis Operation Breakthrough site arrangement showing locations of containers and the compactor	70
22	Thirty-five gallon containers and enclosures as used for refuse in La Clede Town, St. Louis, MO	81
23	Tractor and trailer used by four men to collect refuse from containers in La Clede Town. Refuse is collected six days per week	82

FIGURES (continued)

No.		Page
24	West and east views of pen where La Clede Town refuse is stored for pickup by municipal service	82
25	Closeup photograph of La Clede Town refuse pen which shows bags of refuse intact and broken open, yard wastes, and appliances	83
26	Roll-off 30-cu yd container used at La Clede Town refuse storage pen to supplement municipal removal services	83
27	Typical chute-fed compactor installation in the MFHR buildings	84
28	Typical of the household compactor installations in the MFLR and MFMR buildings in La Clede Town East and West	85
29	Refuse storage pens for refuse from the MFLR and MFMR buildings of La Clede Town East and West sections	84
30	St. Louis site arrangement	86
31	Enclosure for four one-cu yd containers at the Seattle site	101
32	Internal picture of enclosure at the Seattle site	102
33	One-cu yd container from chute-fed refuse rooms awaiting pickup at the Seattle site	102
34	Closeup of one-cu yd containers from chute-fed refuse room at the Seattle site	103
35	Refuse collection at the Seattle site using a rear-loading packer truck	103

FIGURES (continued)

No.		Page
36	Seattle Operation Breakthrough site arrangement showing location of refuse chutes and containers	104
37	Typical chute-fed container installations in the MFHR building at the Sacramento site	112
38	Typical of ten redwood pens and trash cans as used for the MFLR section and one SFA section of the Sacramento site	113
39	Typical backyard area of SFA units which are serviced with backyard pickup at the Sacramento site	114
40	Two rear-loading packer vehicles and crew which serviced the MFLR and most of the SFA units at the Sacramento site	114
41	Box and cart which is used for refuse collection from backyards of one SFA section at the site	115
42	Sacramento Operation Breakthrough site arrangement showing location and type of services	116
43	Refuse (trash) cans set curbside by residents of SFD units at the King County Operation Breakthrough site	125
44	Refuse (trash) cans left curbside behind SFA at the King County Operation Breakthrough Site	125
45	Typical of three 2-cu yd containers used by MFLR residents at the King County Operation Breakthrough site	126
46	Refuse collection crew and 25-cu yd packer truck at the King County Operation Breakthrough site	126

FIGURES (continued)

No.		Page
47	King County Operation Breakthrough site arrangement	127
48	Bagged refuse set curbside for pickup, 122nd Court, King County, Washington	137
49	Bagged refuse set curbside for pickup, 122nd Court,, King County, Washington	137
50	Bagged refuse set curbside for pickup, NE 149th Place, King County, Washington	138
51	Bagged refuse set curbside for pickup, NE 150th Street, King County, Washington	138
52	Site arrangement showing units participating in the plastic bag versus trash can study at the King County site	139
53	Observed total elapsed time to collect refuse in trash cans and plastic bags	143
54	Observed total man-time to collect refuse in trash cans and plastic bags	144
55	Average man-time spent on collection activities for trash cans and plastic bags	145
56	Photographs of trash cans left curbside after pickup	147
57	Refuse spilled from a plastic bag as the result of being torn open by a pet	148

TABLES

No.		Page
1	Operation Breakthrough Sites Refuse Management Systems	2
2	Summary of Economic and Technical Analysis Results	8
3	Demographic and Solid Waste Data for Indianapolis Operation Breakthrough Site	25
4	Cost of Refuse Collection and Disposal at the Indianapolis Operation Breakthrough Site	26
5	Apportioned Costs to Indianapolis Site for Segments of Costs of the Private Service Contractor	28
6	Combined Segments of Annual Expenses for Refuse Collection and Disposal at the Indianapolis Site	29
7	Observed Refuse Collection Activities at the Indianapolis Site for One Pickup and Annually with Analytical Results	31
8	Demographic and Solid Waste System Descriptive Data for the Kalamazoo Operation Breakthrough Site	40
9	Cost of Refuse Collection and Disposal at the Kalamazoo Operation Breakthrough Site	41
10	Apportioned Costs to the Kalamazoo Site for Segments of Costs of the Private Service Contractor	42
11	Combined Segments of Annual Expenses for Refuse Collection and Disposal at the Kalamazoo Site	43
12	Observed Refuse Collection Activities at the Kalamazoo Site for One Pickup and One Year with Analytical Results	45
13	Costs for Kalamazoo Refuse Collection Assuming the Compactors were Properly Utilized	46
14	Demographic and Solid Waste System Data for the Macon, Georgia, Operation Breakthrough Site	51

TABLES (continued)

No.		Page
15	Cost of Refuse Collection and Disposal at the Macon Operation Breakthrough Site	56
16	Estimated Costs to the Macon Site for Segments of Costs of the Private Service Contractor	57
17	Combined Segments of Annual Expense for Refuse Collection and Disposal at the Macon Site	58
18	Observed Refuse Collection Activities at the Macon Site for One Pickup and One Year with Analytical Results	60
19	Demographic and Refuse System Descriptive Data for the Memphis Operation Breakthrough Site	71
20	Cost of Refuse Collection and Disposal at the Memphis Operation Breakthrough Site	73
21	Apportioned Costs to the Memphis Site for Segments of Costs of the Private Service Contractors	74
22	Combined Segments of Annual Expenses for Refuse Collection and Disposal at the Memphis Site	75
23	Observed Refuse Collection Activities at the Memphis Site for One Pickup and One Year with Analytical Results	76
24	Demographic and Solid Waste System Descriptive Data for the St. Louis Operation Breakthrough Site	87
25	Cost of Refuse Collection and Disposal at La Clede Town East and West, the Operation Breakthrough Portions of the St. Louis Site	89
26	Costs of Refuse Collection and Disposal at the La Clede Town Portion of the St. Louis Site	90

TABLES (continued)

No.		Page
27	Summary of Total Cost of Refuse Collection and Disposal at La Clede Town in St. Louis	91
28	Annual Expenses for Cost Elements of Refuse Collection and Disposal at the St. Louis Site	92
29	Demographic and Solid Waste System Descriptive Data for the Seattle Operation Breakthrough Site	105
30	Cost of Refuse Collection and Disposal at the Seattle Operation Breakthrough Site	106
31	Estimated Annual Expenses for Segments of the Refuse Collection and Disposal at the Seattle Site	107
32	Observed Refuse Collection Activities at the Seattle Site for One Week with Projections to One Year with Analytical Results	109
33	Demographic and Solid Waste System Descriptive Data for the Sacramento Operation Breakthrough Site	117
34	Cost of Refuse Collection and Disposal at the Sacramento Operation Breakthrough Site	119
35	Combined Segments of Annual Expenses for Refuse Collection and Disposal at the Sacramento Site	120
36	Observed Refuse Collection Activities at the Sacramento Site for One Pickup and Projections to an Annual Basis	121
37	Demographic and Solid Waste System Descriptive Data for the King County Operation Breakthrough Site	128
38	Cost of Refuse Collection and Disposal at the King County Operation Breakthrough Site	130
39	Combined Segments of Annual Expenses for Refuse Collection and Disposal at the King County Site	131

TABLES (continued)

No. Page

40 Cost of Refuse Collection and Disposal at the King County Site Assuming that all Residents Subscribe to the Private Contract Collection Service 132

41 Observed Refuse Collection Activities at the King County Site for One Pickup and One Year with Analytical Results 133

42 Results From Observations of Plastic Bag Versus Trash Can Pickup at the King County Site 141

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GLOSSARY OF ABBREVIATIONS

SFA	single-family attached dwelling units
SFD	single-family detached dwelling units
MFLR	multifamily low-rise dwelling units
MFMR	multifamily medium-rise dwelling units
MFHR	multifamily high-rise dwelling units
MFM/HR	multifamily medium and high-rise dwelling units
container	An enclosed container of the type designed for being emptied by a packer truck
can	A standard garbage can of usually 30 to 40 gallons capacity which can be manually emptied
dwelling unit	An apartment or a home

TABLE OF CONVERSION UNITS

1 foot = 0.3048 meters

1 mile = 1.6093 kilometers

1 cu yd = 0.7646 cubic meters

1 mill = 0.00254 centimeters

SECTION I

INTRODUCTION

The Department of Housing and Urban Development Operation Breakthrough Program is involved in demonstrating experimental housing design and construction. One of the provisions of the program is to evaluate the refuse collection methods in the program to determine the practicality of the methods and to guide development of solid waste management systems for future projects. The Operation Breakthrough sites and a description of the refuse management systems are presented in Table 1.

The Operation Breakthrough sites at Indianapolis, Kalamazoo, Macon, Memphis, St. Louis, Seattle, Sacramento, and King County are included in this report. The Jersey City site has a pneumatic trash collection system which is being evaluated in detail relative to technical and economic performance. The Jersey City study requires one year of site monitoring and analysis, and the results will be documented in a separate report. In addition to technical and economic performance, a user acceptance survey was conducted for evaluating the refuse management system at each site, and the survey results are included in a separate report.[2]

The specific purpose of this report is to present the results of evaluations of general data gathered during short visits to each site. In addition, the results are presented for a four-week study of the curbside pickup of plastic bags versus standard garbage cans at the King County, Washington, site. A separate report covers an evaluation of refuse system acceptance by residents.

The overall objective of the sponsor of this study is to evaluate the economics, effectiveness, and feasibility of using improved solid waste collection systems in new communities. The results will be used to guide the development of larger scale projects in the future. The specific objectives of the evaluation of the various types of solid waste management systems at the Operation Breakthrough sites

Table 1. OPERATION BREAKTHROUGH SITES REFUSE MANAGEMENT SYSTEMS

	On-site Parameters				Off-site Parameters			
Site	Type of Housing	No. Units	Collection	Storage	Pickup Freq.	Transport	Disposal	Remarks
Indianapolis, IN	SFA	140	Manual	Pens	1/wk	Packer Truck	Land Fill	Municipal service
	SFD	103	Manual	Pens	1/wk	Packer Truck	Land Fill	Municipal service
	MFLR	16	Manual	Container	3/wk	Packer Truck	Land Fill	Private service
	MFMR	36	Chute	Container	3/wk	Packer Truck	Land Fill	Private service
Kalamazoo, MI	SFA	127	Manual	Compactor	Daily	Packer Truck	Land Fill	Transport on-site by site owned dump truck. Off-site transport by private service twice each week.
	SFD	14	Manual	Compactor	Daily	Packer Truck	Land Fill	
	MFLR	52	Manual	Compactor	Daily	Packer Truck	Land Fill	
	MFMR	52	Chute	Compactor	Daily	Packer Truck	Land Fill	
Macon, GA	SFA	159	Packer Truck	Container	2/wk	Packer Truck	Land Fill	Transport on-site and off-site by private service.
	SFD	6	Packer Truck	Container	2/wk	Packer Truck	Land Fill	
	MFLR	42	Packer Truck	Container	2/wk	Packer Truck	Land Fill	
	MFM/HR	80	Packer Truck	Compactor & Container	3/wk	Packer Truck	Land Fill	
Memphis, TN	SFA	69	Packer Truck	Container	3/wk	Packer Truck	Land Fill	Transport on-site and off-site by private service.
	MFLR	99	Packer Truck	Container	3/wk	Packer Truck	Land Fill	
	MFHR#1	144	Packer Truck	Container	6/wk	Packer Truck	Land Fill	
	MFHR#2	206	Packer Truck	Compactor & Container	2/wk	Packer Truck	Land Fill	
St. Louis, MO	SFA	731	Manual	Pen & Container	6/wk	Packer Truck	Power Plant	Municipal service 2/wk
	MFLR	68	Manual	Compactor, Container, & Pen	6/wk 6/wk	Packer Truck	Power Plant	Municipal service 2/wk
	MFMR	147	Manual	Compactor & Container	6/wk 6/wk	Packer Truck	Power Plant	Municipal and private service 2/wk
	MFHR	174	Packer Truck	Compactor & Container	6/wk 2/wk	Packer Truck	Power Plant	Private service 2/wk
King County, WA	SFA	80	Curbisde/Manual	Cans	1/wk	Packer Truck	Land Fill	Private service
	SFD	74	Curbside/Manual	Cans	1/wk	Packer Truck	Land Fill	Private service
	MFLR	24	Packer Truck	Container	1/wk	Packer Truck	Land Fill	Private service
Sacramento, CA	SFA	179	Backyard/Manual	Cans	1/wk	Packer Truck	Land Fill	Municipal service
	SFD	20	Backyard/Manual	Cans/Pens	6/wk	Packer Truck	Land Fill	Municipal service
	MFLR	96	Manual	Cans/Pens	6/wk	Packer Truck	Land Fill	Municipal service
	MFHR	306	Chute/Container	Container	6/wk	Packer Truck	Land Fill	Municipal service
Seattle, WA	SFA	38	Manual/Pen	Container	2/wk	Packer Truck	Land Fill	Private service provided under municipal contract.
	MFLR	20	Manual/Chute	Container	2/wk	Packer Truck	Land Fill	
Jersey City, NJ	MFLR	12	Pneumatic	Compactor Container	Not Applicable	Pull-on Container Truck	Land Fill	Private service
	MFMR	64	Pneumatic	Compactor Container	Not Applicable	Pull-on Container Truck	Land Fill	Private service
	MFHR	410	Pneumatic	Compactor Container	Not Applicable	Pull-on Container Truck	Land Fill	Private service

Note: The results of the evaluation of the Jersey City pneumatic trash collection system will be published in a separate report.

included the following:

1. Describe each solid waste system and provide drawings, photographs, technical specifications where available and as applicable.

2. Analyze the economics of the systems based on available data. The analysis includes considerations of:

   (a) Capital cost of equipment (including installation costs, where applicable).

   (b) Operating costs such as electrical power, labor, maintenance, parts and supplies, fuel, repair costs, container rental, disposable liners, transport and disposal fees.

   (c) Recurring costs such as taxes and insurance.

   (d) All costs results were compared to the "1968 National Survey of Community Solid Wastes Practices[1]" and the results derived from that survey by Hagerty, Pavoni, and Heer.[3] To obtain comparative costs, all site cost data and the results of Hagerty et. al. are modified to a common base in October 1975 using the building and common labor cost indexes found in the Engineering News Record. The 1968 survey results are modified as follows.

"1968 National Survey of Community Solid Wastes Practices"[1,3] National Average costs per capita per year

	1968	Modifier	(ref.)	October 1975
Capital	$1.70	1351.9/754.9	(4)	$3.04/cap./yr
Excluding Capital	$5.11	177/100	(4)	$9.04/cap./yr
Total	$6.81			$12.08/cap.yr

The Operation Breakthrough sites were visited at different times and the costs obtained at each site are modified as follows.

Site	Cost Modifiers		
Date of Visit	Material and Installation Cost Indexes	Other Cost Indexes	References
Indianapolis, Indiana			
September 1973	1351.9/1158.1	4525.6/3800.4	(4,5)
September 1975	1351.9/1333.7	4525.6/4512.8	(4,6)
Kalamazoo, Michigan			
September 1973	1351.9/1158.1	4525.6/3800.4	(4,5)
Macon, Georgia; Memphis, Tennessee			
October 1973	1351.9/1154.8	4525.6/3802.4	(4,7)
St. Louis, Missouri			
July 1974	1351.9/1238.7	4525.6/4030.7	(4,8)
Seattle, Washington; Sacramento, California; King County, Washington			
April 1975	1351.9/1273.2	4525.6/4204.9	(4,9)

It should be noted that Indianapolis was visited twice and cost data from both visits are utilized and modified by the appropriate cost modifier.

In addition to cost projections to October 1975, capital equipment costs are annualized by multiplying by a carrying charge. The carrying charge is the sum of an interest rate plus a sinking fund factor for depreciable capital costs. For non-depreciable capital costs, the carrying charge consists of just the interest rate. The carrying charge is

$$i + [i/(1+i)^n - 1]$$

where: i is the interest rate
n is the number of years of depreciation

In all instances the number of years of depreciation is considered to be the expected life of the equipment. A 7.5 percent interest rate is used for all cost evaluations.

3. Analyze the technical aspects of the systems to determine the effectiveness and efficiency. The

technical analysis includes consideration of:

(a) Quantity of solid wastes collected in terms of type and number of containers at each service and the number and type of dwelling units.

(b) Distances traveled between services and total distance to collect on site.

(c) Distances from the collection vehicle to the storage areas.

(d) Time spent on various collection activities including productive collection time, handling and walking time, waiting time, and time spent on other activities.

(e) Mechanical equipment performance effectiveness, safety, convenience, user acceptance, noise, odor, sanitation, aesthetics, and other aspects pertinent to each system.

(f) Compactor (where installed) load capacity and the weight, size, and handling requirements of compacted packages.

(g) Storage containers effectiveness, sanitation, user acceptance, and other aspects pertinent to each system.

The approach for accomplishing the above objectives consists of visiting each site and recording the required data. Solid waste system descriptive and economic data are obtained from site management and other sources (HUD, builder, contract hauler) as required. Technical data are obtained through short-term observations of solid waste management practices for the eight sites. Time and motion study estimation techniques are used to gather sufficient data for determining the technical effectiveness and efficiency of seven sites. Detailed time and motion study techniques are used to perform a comparative study of plastic bag versus standard containers for curbside collection at the King County site. For the special study, half of the King County residences were furnished plastic bags for lining trash cans. On pickup day, the plastic bags were tied and set at curbside. The other half of the residences utilized standard cans in the usual manner by setting them at curbside on pickup day. The data were collected over a one month period for comparing the halves on the basis of economics, collection efficiency, aesthetics, sanitation, and other pertinent aspects.

User or resident acceptance of the solid wastes management systems was determined by surveying a sample of the residents and the management at each site by conducting interviews using an approved survey questionnaire. The results of the analysis are analyzed to determine the type of use, user solid waste disposal requirements, suitability of the system to the user, and suitability of the system with respect to the environment of the user. This program was approved by the Office of Management and Budget. The results of the analysis are provided in a separate report[2] and an overall summary report, separate from this report, except for the St. Louis site where approval to survey residents was denied.

SECTION II

CONCLUSIONS

This report presents the results of evaluations of solid waste management system data gathered at eight Operation Breakthrough sites. In addition, the results are presented for a four-week study of the curbside pickup of plastic bags versus standard garbage cans at the King County, Washington, site. The overall objective of this study is to evaluate the economics, effectiveness, and feasibility of using improved solid waste collection systems in new communities. The major results from the economic and technical evaluations of each site are summarized in Table 2. All economics data were adjusted to reflect cost as of October 1975 as explained in the Introduction, Section I. Only three of the eight sites approach the adjusted National averages for cost of refuse collection and disposal. Indianapolis, Sacramento, and King County are lowest in cost per capita per year. Specific conclusions for each site are stated below.

INDIANAPOLIS, INDIANA

The system is satisfactory in that refuse is collected and disposed. The city charges for collection for the entire site even though the MFMR and the maintenance buildings are serviced by a private contractor. The costs (adjusted to October 1975 basis) are $2.22 per cu yd which is reasonable and equates to $44.38 per dwelling unit per year. The costs could be reduced if the city services the entire site. The total costs are $12.62 per capita per year (average) which is higher than the adjusted national average of $12.08 per capita per year. Site labor requirements could be reduced if residents were required to store refuse in their homes until pickup day. At present, considerable site labor is required to clean the refuse pens each week because of bagged refuse exposure to weather, insects, and animals.

The manual pickup by the city incurs a high nonproductive rate with 35 percent of the active collection time spent waiting.

Table 2. SUMMARY OF ECONOMIC AND TECHNICAL ANALYSIS RESULTS

Site	Annual Costs	Cost/DU/ Year	Cost/ Cap./yr	Cost/ cu yd	Miles per stop	DUs per stop	Man-minutes per stop	Man-minutes per cu yd
Indianapolis	$13.091	$44.38	$12.62	$2.22	0.2	8.4	8.2	2.5
Kalamazoo	15,072	51.09	14.52	2.55	0.1	13.6	9.7	15.2
Macon	21,105	73.53	28.52	3.52	0.1	4.9	8.0	4.1
Memphis	22,614	43.65	25.35	2.25	0.1	26.1	9.4	3.0
St.Louis	124,541	111.20	46.00	8.24	33.1 miles per week	32.6 DUs per mile	11.3 man-minutes per DU	42.9 man-minutes per cu yd
Seattle	4,727	81.50	22.19	5.56	0.03	18.7	26.5	5.0
Sacramento	14,486	24.10	11.34	2.68	0.1	20.1	9.6	7.8
King County	9,540	53.90	13.65	4.54	0.1	8.4	6.5	3.4

NOTES· (1) Details of costs for each site are given in Section IV and are adjusted to include all costs associated with refuse management including capital, recurring, and operating and maintenance costs.

	Advantages	Disadvantages
Indianapolis	Low cost	35 percent nonproductive use of labor. Odors, insects, weather effects occur.
Kalamazoo	Proper compactor use could result in low costs and reduction in required service frequency. Good aesthetics. Free from odors, insects, vermin.	Poor effectiveness. Residents do not use compactors. High capital costs. High maintenance costs. 17 percent nonproductive use of labor. Excessive refuse handling which is labor intensive.
Macon	High effectiveness. Low capital costs. Clean and free from odors, insects, vermin.	Improper compactor installation causes increased costs. High maintenance costs. 13 percent nonproductive use of labor. Serviced too frequently. Noisy collection. Litter in MFM/HR trash room.
Memphis	Low capital costs. Very effective. Good aesthetics. Free from odors, insects, vermin. No sanitary problems.	Municipal inspection fee of $0.50 per DU per month. High operating costs. Overhead clearance not sufficient for front loader truck. Containers do not fit pens. 23 percent nonproductive labor utilization. Safety problem moving containers on casters.
St. Louis	The compactors in the Operation Breakthrough portions would be an advantage if properly utilized.	Excessive costs. Compactors are not effectively utilized. Excessive handling of refuse which is labor intensive. Poor effectiveness, Sanitary problems with odors, insects, vermin. Storage pen is overloaded.
Seattle	Low capital costs. Very effective. Excellent appearance. Clean and free from odors, insects, vermin.	High collection service costs. 22 percent nonproductive labor utilization. One portion serviced too frequently.
Sacramento	Low costs particularly low capital costs. Good effectiveness. Excellent appearance. Clean and free from odors, insects, vermin.	High collection costs. Labor intensive. Overloaded pens.
King County	Low costs for subscribers to refuse service contractor. No problems with odors, insects, vermin.	High costs for residents disposing their own refuse. Cans left curbside detract from site aesthetics.

Site environmental aspects are generally good. Site aesthetics could be greatly improved if shrubbery were planted around the pens. Restriction of residents to placing refuse in pens only on collection days could minimize odors, insects, and animal problems. Refuse protection in the home should not result in storage problems if bags are properly used; in fact, it should increase the care taken by residents to minimize problems through proper tying of bagged refuse.

KALAMAZOO, MICHIGAN

The system is not being properly utilized; therefore, the full effectiveness of the design of the system is not being achieved. Excessive costs are incurred for pickup labor, plastic bags, on-site hauling, and disposal costs. The total costs observed are $2.55 per cu yd of loose refuse. Costs could be reduced to $2.29 per cu yd if proper compaction operation were performed by site residents. The $2.29 per cu yd is based upon proper utilization of the compactors which would then allow reduction of pickups from seven to three per week by site maintenance personnel and reduction to one pickup per week by the private service contractor.

Residents do not start the compactors. Trash is placed inside the compactors if the chamber is not full, but the residents do not push the start button after placing refuse inside. Subsequent visits by residents result in refuse being left on the ground around the compactor rather than compacted in the chamber.

The use of plastic bags in the chamber of the compactor created a safety hazard due to broken glass. This has resulted in the need to segregate glass from the trash. It is recommended that a metal, hinged carrying "caddy" or similar device be devised for handling compacted packages which are removed for disposal.

MACON, GEORGIA

The refuse system is effective, efficient, and fairly economical. A lack of design consideration is evident in the refuse chute to compactor interface. Future projects should specifically give more consideration to refuse room location, refuse chute location, and compactor installation so that the necessary space is allowed for a proper installation of the equipment. The containers as well as the pens in most cases blend well into the site. Some of the containers do not blend into the site. Consideration should be given to specifying the color of containers such that they do not detract from the site. Also, container locations should receive more consideration for access by the service truck.

Refuse rooms, where residents need not open doors, should be closed and possibly locked at all times when not being attended. Walking time and some nonproductive labor can be reduced. It will not reduce overall costs much, but consideration for future sites should include planning to improve labor utilization. The containers inside of pens must be rolled out and positioned in front of the packer truck. After emptying the container must be rolled back. Future sites should contain provisions for allowing direct access to the container by the truck. Packer trucks should have some provision to prevent liquids from being squeezed out of the truck onto the parking lot or grounds of a residential area. This type of refuse system should not be affected by weather conditions except ice or snow which may prevent the packer truck from being operational.

MEMPHIS, TENNESSEE

The refuse collection system is economical. Future compactor installations should consider the basis of hauling and disposal charges during the planning stages. If reduced volume does not save money, the only reason to install the equipment is to reduce the number of pickups. The system as installed at Memphis requires a private contractor to remove and dispose refuse which is the single most expensive part of the system. The contracts account for 55 percent of the annualized system costs. The concrete pens do serve to blend the containers into the site; however, future sites should more closely match pen size to container size so that the container will fit into the pen. Also, pen orientation should be considered for ease of emptying by the truck. Container size and method of emptying should be considered where there may be limited overhead space. The system has no apparent odor, sanitation, or noise problems. The container-to-truck interface,when using containers in high-rise structures,must be considered in terms of the method of moving to the truck. A hazardous situation exists because the containers must be manually pushed down inclined ramps to the truck. This requires dexterity and a fair amount of strength to prevent the heavily ladened containers from running wildly down the inclines possibly crashing into automobiles in the parking lots or injuring personnel.

The manual movement of the containers is consumptive of time and labor. The 144-unit MFHR building should have been a serious candidate for compactor installations because of the number of tenants. Presently, the containers are emptied once each day, six days a week. Installation of compactors should reduce the number of pickups to a maximum of three pickups per week. This would not reduce dumping charges, but it should reduce pickup fees and reduce the labor expended in removing backed-up refuse in the chute.

ST. LOUIS, MISSOURI

The system is not economical for the entire site. The effectiveness and efficiency of the refuse collection system is degraded by the labor intensive efforts and excessive handling of refuse. Curbside pickup would benefit the La Clede Town portion of the site by eliminating the need to place refuse in containers and then move refuse from containers to street areas for pickup. Similarly, the refuse is then placed in pens to await pickup and disposal by the municipal service and by private contractor. A recommended improvement is to eliminate excessive handling of the refuse.

The existing system is not aesthetically obtrusive. All containers and pens are well disguised by shrubbery. The storage pens are outside and the sanitation is questionable because refuse builds up in the pens, decays, attracts flies, causes extreme odor problems, and probably attracts vermin. Also, excessive handling of the bagged refuse caused bag tears and refuse spillage which increases the probability that storage problems occur.

A complete study should be performed so that the refuse management system could be improved. A study of once-only-handling of refuse should be included in the study. By decreasing handling, it would probably decrease costs and sanitary problems and increase efficiency and effectiveness. Curbside pickup and disposal by the site, the city, or a private contractor may offer cost benefits to the site.

SEATTLE, WASHINGTON

The Seattle site refuse system is effective, efficient, and environmentally satisfactory. The annual costs appear high due to the costs of the city provided collection and disposal service. The costs could be lowered by servicing the chute-fed containers once a week. The efficiency of the collection crew could be improved at the site if a one or two man crew was used in place of the three-man crew, because one man stands idle while collection is performed at the site (this reduction may not be possible due to requirements for personnel when servicing urban areas other than the Operation Breakthrough site).

SACRAMENTO, CALIFORNIA

The capital costs for the Sacramento site refuse system are low and the operation and maintenance costs are high. Collection and disposal fees account for 71 percent of the costs of the refuse system. Overall, the costs per dwelling unit, per capita, and per cu yd of refuse are fairly low and are less than national averages.

Excellent efficiency is achieved in refuse collection activities at the site. The effectiveness and efficiency of collection in terms of cost are high, but the volume of refuse collected per unit of time appears low which is due to the backyard collection activities required to service 295 dwelling units.

Odors occur in the trash can pens in hot weather. The system exhibits no environmental problems associated with aesthetics, noise or sanitation. Resident requirements for handling refuse are minimal.

KING COUNTY, WASHINGTON

Refuse collection and disposal at the King County site is very effective with the exception of the residents who dispose of their own refuse. Curbside collection once a week using a two-man crew is efficient and environmental problems are minimized. The refuse system would be much more economical if all SFA and SFD residents subscribed to the private collection service. It is an option of the homeowner to subscribe or dispose of his own refuse.

KING COUNTY PLASTIC BAG STUDY

The use of plastic bags in place of standard trash cans results in $17.41 higher annual costs to the homeowner. Refuse collection activities are more efficient and require less labor when plastic bags are utilized. Refuse is collected faster when plastic bags are used; however, the contractor will not reduce pickup fees even if bags are used. The collection crew prefers plastic bags because of increased pickup speed. The site appearance is improved because cans are not left curbside in the SFD areas after pickup of refuse. Site environmental conditions are as good or better when plastic bags are used. There is less collection noise when plastic bags are collected. Odors are minimized and there appears to be less possibility of sanitation problems when plastic bags are used. Overall, a site would appear to be improved if plastic bags are used in place of trash cans for curbside pickup, however, heavy duty bags (3-mil thickness) were used in the study and bags of less strength might have different results.

SECTION III

RECOMMENDATIONS

Planning for future developments should include detailed consideration of refuse management requirements. The requirements should be incorporated into designs during development of site plans and buildings to assure adequate considerations for installation, location, and operation. Particularly important is the planning required for innovative systems which may have unusual requirements or may not be acceptable to residents. The results and conclusions of the study demonstrate that conventional collection methods such as curbside, chute, and dumpster containers are easily used by residents whereas innovative methods are not properly utilized by residents. Recommendations for each site follow:

INDIANAPOLIS, INDIANA

Methods should be studied to allow municipal servicing of the MFMR building as well as the rest of the site because the site pays the city for the service even though it is not used. The $1824 per year paid to the private contractor could be saved if the city serviced the MFMR building and the site hauled bulky wastes away. If similar to the rest of the site, the refuse would have to be stored in plastic bags and placed in a pen for city pickup. The city utilities department has indicated that this is possible.

A regulation not allowing residents to place bags of refuse in the pens except on pickup days should be considered. This would influence residents to properly close and tie bags and prevent exposure to weather and animals (pets, mostly cats and dogs). A top to the pens would help prevent weather effects but would prevent the cleansing effect of direct sunlight; therefore, a top is not recommended.

Crew performance efficiency would be greatly increased if the truck driver participated in refuse handling. Over seventy percent of his time is spent waiting while two crew members load the truck. Possibly, a switch to a crew consisting of a driver and a loader (two men) would greatly increase utilization of personnel.

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Methods should be considered to install a slope from the vertical chute to the container in the MFMR building. The current design results in chute clogging and backups with scattered refuse in the container room. Future buildings of this type should have provisions for the container to be placed under the chute and to have a plate valve to close the chute when the container is being serviced.

KALAMAZOO, MICHIGAN

Considerable effort on the part of the site management has not resulted in residents using the communal compactors so that maximum benefits of refuse volume reduction are realized. It is doubtful that the residents will ever properly utilize the equipment; therefore, it is recommended that curbside pickup once a week be initiated at the site with a one or two-man crew. Another alternative is to use centrally located containers serviced by a private contractor.

If communal compactors are considered for future developments, automatic cycling would be a desireable feature. The charging chamber should also be located at least 36 to 42 inches above the ground to prevent entry by adventuresom youngsters. The higher location would allow easier servicing by the collection crew. The greatest benefit that automatic cycling attains is the reduction of refuse volume which requires fewer servicing trips by the collection crew. A special carrying device should be used with compacted refuse to prevent injuries to service personnel. A two handled device could be easily developed as a caddy for bags of compacted refuse.

MACON, GEORGIA

The use of central containers works very well. Future site planning should incorporate better locations for containers to allow easy access by the pickup truck. Container enclosures should be oriented to prevent the containers from being very noticeable. The planting of shrubbery instead of (or in addition to) using frame enclosures might also be considered to improve aesthetics.

The compactor installation under the chute of future multilevel buildings should consider the interface problems before installation so that adequate space is allowed to provide a proper fall for refuse to enter the compactor chamber. Refuse container rooms should be locked to prevent entry by people and pets. Compactor containers should have metal or canvas compactor-port covers to prevent spillage when moving or emptying the containers.

MEMPHIS, TENNESSEE

The site is charged landfill fees on a loose refuse basis. A four to one compaction ratio means the site is charged four times the loose refuse price; therefore, compacting the refuse has not saved money. Future developments should consider the basis of landfill fees before installing compaction equipment. The equipment does allow fewer service trips by the contracted pickup service.

Future sites which use container enclosures should design and install enclosures of sufficient size to allow the container to be fully inserted into the enclosure. The enclosures at the Memphis site are too small and would be difficult to modify since they are concrete. The use of containers should also consider the method of emptying the containers. The containers under the deck must be lifted and moved to an overhead opening for emptying by the top loading packer truck. The containers in the high-rise buildings must be rolled downhill along a sidewalk to curbside for emptying; therefore, the weight of the container plus refuse can present handling problems to personnel. The containers could get away from the crew and cause personal injury and property damage. Future sites should allow the pickup truck to move to the trash rooms to service containers.

The Adult Student Housing high-rise building is an excellent candidate for use of compactors under the refuse chutes. The six-day a week servicing could be reduced to servicing three times a week (or less). Landfill fees would not be saved, and a method to safely move the containers to curbside would have to be developed.

ST. LOUIS, MISSOURI

The St. Louis site refuse system has many problems and a complete in-depth study of the refuse management system is desparately needed. Such a study is recommended and it should incorporate the following minimum features. Study the possibility of once or twice a week curbside pickup in La Clede Town to reduce refuse handling and storage. Pickup the refuse from the Operation Breakthrough portions (La Clede Town East and West) only once a week since all households have compactors. Store refuse in containers which can be dumped by trucks rather than requiring manual loading. The containers would help minimize odors, insects, and vermin problems. The site should consider purchasing a packer truck and providing curbside collection for disposal of refuse.

SEATTLE, WASHINGTON

The chute-fed containers do not need emptying twice a week. Either by adding one or two containers, once a week service could reduce the costs of servicing the site. The refuse rooms are locked and being underground are cool, odor free, and insect free.

SACRAMENTO, CALIFORNIA

The Sacramento site refuse management system is very effective. Some overloading in some of the multi-family-low-rise (MFLR) pens occurs while other pens are virtually unused. It is suggested that the pens be better located for use by residents. The pens near automobile parking areas are frequently overloaded; therefore, additional pens in those areas might solve the problem. Another approach is to move the three pens in the MFLR alleys to the curbs of the parking lots. Ten pens appear adequate for the load.

The high-rise buildings should have compactors installed to reduce pickup frequency. The buildings have plenty of space under the refuse chutes where compactors would easily fit. The installation could easily reduce servicing from six days a week to three times (or less) a week.

KING COUNTY, WASHINGTON

All residents of the King County site should subscribe to the refuse collection service. Thirty-five residents that haul their own refuse away could save money by subscribing to the service. No other recommendations are made for the site.

SUMMARY FOR FUTURE DEVELOPMENTS

Single family attached (SFA) and detached (SFD) housing developments appear to be most effectively serviced by curbside, once a week pickup of refuse. Multifamily-low-rise (MFLR) buildings can effectively utilize curbside pickup but should probable be serviced with centrally located containers. Household compactors can only be recommended if once a week pickup will be used and residents are taught to use their compactors. Communal compactors are not recommended; but, if used, they should automatically cycle without relying on residents to actuate the units.

Communal compactors must also be carefully designed and installed to preclude entry by children and injury to personnel when handling the compacted package.

Multifamily-medium (MFMR) and high-rise (MFHR) buildings should always be candidates for chute-fed compactors. Specific attention should be focused on allowance of space for proper equipment installation. Also, designs should provide easy access for servicing by a packer truck to minimize manual handling of containers.

The special plastic bag study at the King County site showed definite advantages to use of plastic bags in place of containers. A warmer time of day for pickup or a warmer climate might change the results if bags weaken. Only heavy duty bags are recommended if a plastic bag requirement is instituted.

SECTION IV

DATA COLLECTION AND ANALYSIS

INDIANAPOLIS, INDIANA

The Indianapolis site was visited on September 16 and 17, 1973, and revisited on September 4, 1975. At the time of the first visit, the site was exploring the use of centrally located storage pens in place of centrally located 2-cu yd containers. The second visit was made after the transition was completed. The reason for the change by the site was economics; the city billed the site for refuse collection and disposal even though the site contracted with a private hauler to service the containers. The system consists of 24 redwood pens centrally located for residents of the SFA, SFD, and MFLR dwelling units. One 2-cu yd container (dumpster type) is located under a trash chute in the MFMR. Two 4-cu yd containers (dumpster type) are located at the clubhouse for disposal of yard and bulky wastes. The storage pens are serviced once a week by the city, and the containers are serviced three times a week by a private contractor. Figures 1 through 3 are photographs of typical pens, the chute-fed container, and the typical bulky wastes container. The site arrangement is shown in Figure 4. The site demographic and other data are given in Table 3.

Refuse Storage Description

SFA, SFD, and MFLR residents of the Indianapolis site take their refuse to a storage pen. The 24 pens are serviced once a week by municipal service. The city uses a rear-loading packer truck with a driver and two helpers. The crew is paid on the basis that serving 900 dwelling units equals an eight-hour day of work. Site residents using the pens are required to place refuse in plastic bags before disposal in the pens. The municipal service will not pick up refuse that is not in a plastic bag. Once a week, the municipal service sends a rear-loading packer truck. The truck is backed to the door on each pen where the two helpers load the bagged refuse. The estimated site load from pens is 79 cubic yards per week (or per pickup day) which almost loads the truck which is capable of handling 20 cubic yards of packed refuse (equivalent to 80 to 100 cu yd of loose

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NO
BOXES OR
LOOSE
GARBAGE

Closeup View with Door Open

Distant View with Door Closed

FIGURE 1. Typical of 24 refuse storage pens at the Indianapolis Operation Breakthrough site. Only plastic bags are allowed and are collected by the municipal refuse service.

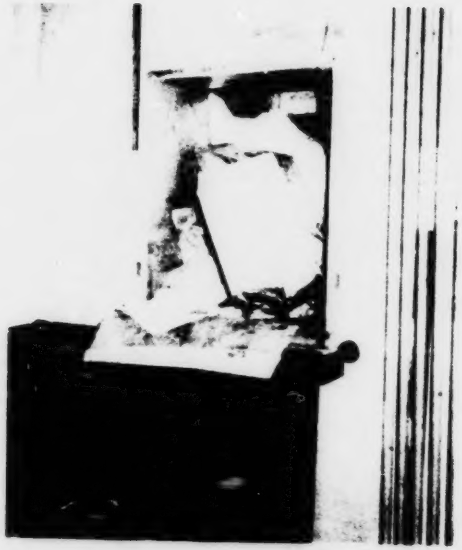

FIGURE 2. Trash chute base and container in MFLR building at the Indianapolis site. Note the right angle feed to the container which results in daily chute blockage.

FIGURE 3. Typical of two standard 4 cu yd containers at the Indianapolis Operation Breakthrough site.

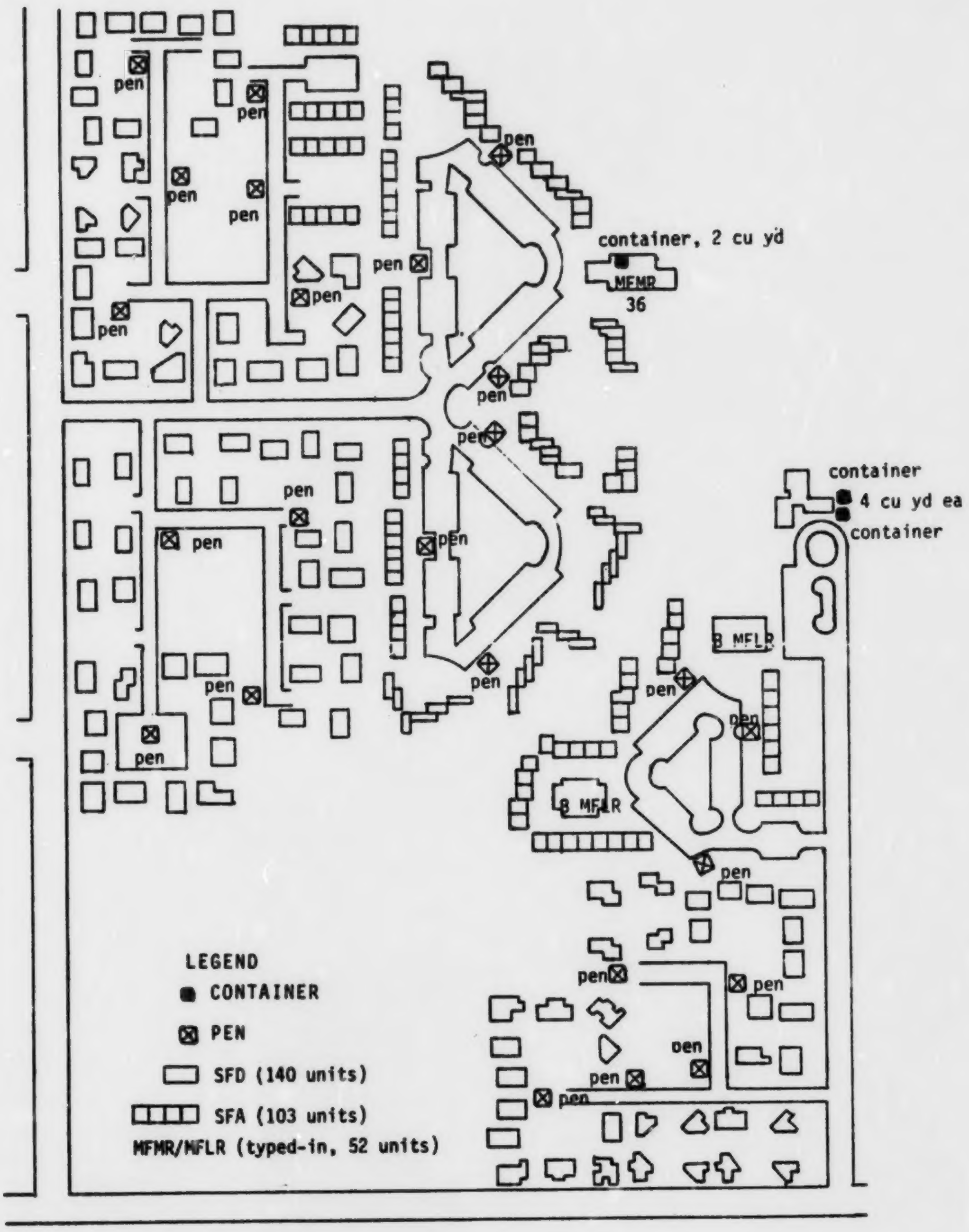
pen
pen
pen
pen
pen
pen
container, 2 cu yd
MFMR
36
pen
pen
pen
pen
container
4 cu yd ea
container
pen
pen
pen
8 MFLR
pen
pen
pen
8 MFLR
pen
pen
pen
pen
pen
pen
pen
LEGEND
● CONTAINER
☒ PEN
SFD (140 units)
SFA (103 units)
MFMR/MFLR (typed-in, 52 units)

FIGURE 4. Indianapolis Operation Breakthrough site arrangement of pens and containers. The number of MF units is indicated with the building.

Table 3. DEMOGRAPHIC AND SOLID WASTE DATA FOR INDIANAPOLIS OPERATION BREAKTHROUGH SITE

Number and Types of Dwelling Units

Type	
SFA	140 units
SFD	103 units
MFLR	16 units
MFMR	36 units
Total	295 units

No. occupied	253 units	
No. residents	890 people	(prorating to 295 units indicated 1038 people)
Site area	42.9 acres	

Distribution of Units by Type of Service

Number and Type	Pens	Containers
103 SFD	13	
156 SFA/MFLR	11	
36 MFMR		1 (chute fed)
1 Clubhouse		2

Average number of units/service = 10.5
Average number of people/service = 38.4

refuse). When full, the truck is emptied at a landfill eight miles from the site; however, the truck is not full after servicing the site and other city residential areas are serviced before and after the site is serviced. Pen cleanup and maintenance and collection of bulky refuse are performed by site employed personnel.

The three dumpster-type containers are serviced three times each week by a private contractor. A front-to-overhead packer truck is used with only a driver. Residents place refuse in the containers. The estimated load is 10 cu yd per pickup day or 30 cu yd per week. The truck services other areas in addition to the site. Cleanup around containers and pickup of bulky wastes are performed by site personnel.

Economic Analysis

Economic data are tabulated in Table 4 in general form. The municipal service charges were discussed with the Department of Sanitation to determine the elemental costs.

Table 4. COST OF REFUSE COLLECTION AND DISPOSAL AT THE INDIANAPOLIS OPERATION BREAKTHROUGH SITE

	Initial Costs	Multi-plier[a]	Oct. 1975 Cost	Carrying Charges[b]	Annual Costs	Cost/DU/yr (295)[c]	Cost/Cap/yr (1038)[c]	Cost/Cu/yr (5900 cu yd/yr)[c]
Capital Costs								
Storage pens 24x$275 each (7-1/2 year life)	$6,600	1.1673	$7,704	0.179	$1,379			
Chute, Dillon Bldg. (40 year life)	$1,800	1.1673	$2,101	0.079	166			
					$1,545	$5.24	$1.49	$0.26
Recurring Costs								
Direct municipal charges[d]	$ 866	1.1908	$1,031	NA	$1,031			
Other municipal funding[e]	$1,546	1.1908	$1,841	NA	$1,841			
					$2,872	$9.74	$2.77	$0.49
Operation and Maintenance Costs								
Site labor (pen cleanup and bulky item collection)[f]	$2,321	1.0028	$2,327	NA	$2,327			
Site labor supervision[g]	811	1.0028	813	NA	813			
Pen repair labor[h]	1,728	1.0028	1,733	NA	1,733			
Pen repair materials[i]	300	1.1673	350	NA	350			
Private contract services[j]	1,800	1.0136	1,824	NA	1,824			
Plastic bags[k]	1,394	1.1673	1,627	NA	1,627			
					$8,674	$29.40	$8.36	$1.47
Total Annual Costs:					$13,091 per year	$44.38 per DU per year	$12.62 per capita per year	$2.22 per cu yd

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a - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.

b - The carrying charge is interest plus sinking fund factor. See Section I for explanation.

c - Occupancy was 253 dwelling units out of 295 at the site. The number of residents and the observed refuse collected are multiplied by 295/253 to adjust to total site occupancy result (September 1973 data).

d - $866 is collected by the city as 40% of sanitary fees and as part of site taxes (September 1973 data).

e - The $1543 municipal funding was estimated based upon cost data furnished by the city (September 1973 data).

f - 12 man-hours per week at $3.10/hr plus 20% fringe benefits (September 1975 data).

g - 2 man-hours per week at $6.50/hr plus 20% fringe benefits (September 1975 data).

h - 20 man-hours per month at $6.00/hr plus 20% fringe benefits (September 1975 data).

i - $25/month for repair material for all 24 pens (September 1973 data).

j - $150/month for one 2 cu yd and two 4 cu yd containers emptied three times each week (September 1975 data).

k - 536 plastic bags per week at $0.05/bag (September 1973 data).

The information obtained indicated the following elemental costs to the city (in September 1973 costs):

Sept. 1973	
$ 27	per day truck investment recovery
12	operation and maintenance
15	landfill costs (fees)
76	labor, salaries of driver plus two helpers
23	labor fringes at 30 percent
12	supervision of a crew
$165	per day

The service classification for the site is "apartment," and a crew is expected to service 900 apartment units per day. These costs on a fractional basis indicate that the annual cost to the city for servicing the site is:

($165/day)x(253/900)x(52 service days/year)=$2412/year

The total cost to the city is almost three times the amount ($866) directly paid by the site. It is apparent that the city subsidizes refuse collection from general revenue funds. The $1546 subsidy from general revenues is indicated as other municipal funding in Table 4. The results can be compared with the results of the "1968 National Survey of Community Solid Wastes Practices."[1] (See Section I for adjustment to obtain October 1975 costs.) The site costs are $12.62 per capita per year as compared to the national average of $12.08 per capita per year.

The private contractor servicing three containers provided information relative to expenses of collection and disposal of refuse:

Capital Costs (September 1973 data, multiplier is 1.1673)		October 1975 Expenses/Year (% of total)
$28,000	truck, 5-year amortization, carrying charge is 0.247	$6,916/yr (23%)
$ 160	ea., 2-cu yd container, 10-yr amortization, carrying charge is 0.146	$ 23/yr (negligible)
$ 190	ea., 4-cu yd container (two), 10-yr life carrying charge is 0.146	$ 55/yr (negligible)
Recurring Costs (multiplier is 1.1673)		
Insurance, taxes, licenses $800/yr		$ 934/yr (3%)

Operating and Maintenance Costs

Labor @ $150/40-hour week (multiplier is 1.1908)	$ 9,288/yr	(31%)
Supervisions @ 15% of labor	$ 1,393/yr	(5%)
Landfill costs @ $18.75/load (498 loads/yr) (multiplier is 1.16731)	$10,900/yr	(36%)
Operating costs @ $10/day (multiplier is 1.1673)	$ 607/yr	(2%)
Total Costs	$30,116/yr	(100%)

Using the above figures, the expenses can be apportioned to the site as shown in Table 5. The costs are shown in the far right column of Table 5 as the three container price for three pickups per week. The prices to the site include profit to the private contractor.

The expense associated with each element of refuse collection and disposal can be estimated and analyzed. The combined municipal, private service, and site expenses are detailed in Table 6. Sixty-nine percent of the annual expenditures is for labor and plastic bags.

Table 5. APPORTIONED COSTS TO INDIANAPOLIS SITE FOR SEGMENTS OF COSTS OF THE PRIVATE SERVICE CONTRACTOR

	Apportionment Factor	October 1975 Three Container Annual Costs to Site
Capital Costs		
Truck	23%	$ 420
Containers	negligible	negligible
	23%	$ 420
Recurring Costs		
Insurance, licenses, taxes	3%	$ 55
Operation & Maintenance Costs		
Labor w/30% fringe benefit	31%	$ 565
Supervisory costs	5%	91
Landfill costs	36%	657
Operating costs	2%	36
	74%	$1,349
Total Annual Costs:	100%	$1,824

NOTE: Costs to site include contractor profit.

Table 6. COMBINED SEGMENTS OF ANNUAL EXPENSES FOR REFUSE COLLECTION AND DISPOSAL AT THE INDIANAPOLIS SITE

	Municipal	Private	Site	Segment Total	% of Annual Total
Capital Costs					
Truck	$ 463	$ 420	--	$ 883	7%
Containers		--	--	--	-
Storage pens		--	$1,379	1,379	11
Refuse chute		--	166	166	1
	$ 463	$ 420	$1,545	$ 2,428	19%
Recurring Costs					
Insurance, taxes, licenses	(included above)	$ 55		$ 55	-
Operation & Maintenance Costs					
Labor	$ 1,937	$ 656	$4,873	$ 7,466	57%
Operating, maintenance	212	36	350	598	5
Landfill fees	260	657		917	7
Plastic bags			1,627	1,627	12
	$ 2,409	$1,349	$6,850	$10,608	81%
Totals	$ 2,872	$1,824	$8,395		
Annual Total				$13,091	100%

Technical Analysis

The collection and disposal of refuse at the Indianapolis Operation Breakthrough site was observed for three days. The municipal service collected about 67 cu yd, and the private contractor collected about 10 cu yd. The city collects once each week and the contractor empties the containers three times each week:

67 cu yd/week x 52 wk/yr = 3481 cu yd/year
10 cu yd/pickup x 156 pickup/yr = 1560 cu yd/year
Total estimated annual load = 5041 cu yd/year

Site occupancy was 253 units occupied (219 served by city, 34 served by contractor). Expanding the data for a fully occupied site of 295 dwelling units results in 5900 cu yd of refuse collected per year. The technical data are summarized for the municipal service, the private contractor service, and the combined services of both. The data collected and analyzed include total distance traveled, number of stops, refuse per unit time, stops per unit time, and time spent in various pickup activities by the crews. The data are shown in Table 7 for the site as it was observed on September 4, 1975. The site was 85 percent occupied. The nonproductive time is considered as all waiting and packing time and is 35 percent of the total labor spent in collection activities.

Equipment Performance -

There are very few pieces of equipment involved, but the following generalizations are made about the equipment performance:

Suitability - The system works in that refuse is collected and disposed. The chute in the MFMR building clogs up because there is lack of slope from the vertical fall to the container (see Figure 2) which is offset from the chute. This is a nuisance when the container is removed because considerable time is required to clean up the room during and after container removal.

Effectiveness - Except for chute clogging in the MFMR, the system is effective for refuse collection. The system is not effective with respect to labor utilization because only 65 percent of the man-time is productively utilized during refuse collection on site.

Table 7. OBSERVED REFUSE COLLECTION ACTIVITIES AT THE INDIANAPOLIS SITE FOR ONE PICKUP AND ANNUALLY WITH ANALYTICAL RESULTS

Service	Distance Travelled	No. of Stops	No. of Units	Crew Size	Items Collected	Estimated Volume	Time Elements				
							Elapsed	Riding	Walking/Handling	Waiting/Packing	Total Man-Time
Municipal (One pickup per week)	2.6 miles	24	218	3	453 plastic bags	67 cu yd (loose)	4210 seconds	2984 man-sec.	5368 man-seconds	4278 man-seconds	12,630 man-seconds
Private (Three pickups/week, data are for one pickup)	1.5 miles	2	35	1	3 containers	10 cu yd (loose)	723 seconds	177 seconds	260 seconds	286 seconds	723 seconds
Total Per Year	369 miles per yr.	1560 stops per yr	253 units serviced	-	-	5044 cu yd per yr	92 hours/ year	51 man-hours per year	89 man-hours per year	74 man-hours per year	214 man-hours per year

ANALYTICAL RESULTS:

Average distance per stop: 0.2 miles per stop
Average labor per stop: 8.2 man-minutes per stop
Average dwelling unit density per stop: 8.4 dwelling units per stop
Average labor per cu yd: 2.5 man-minutes per cu yd
  Riding 0.6 man-minutes per cu yd
  Walking & Handling 1.0 man-minutes per cu yd
  Waiting & Packing 0.9 man-minutes per cu yd

Resident Acceptance - An analysis of the results of a survey of a sample of residents concluded that the residents are relatively pleased with the system even though they experienced overloading of pens resulting in littering, odors, dog nuisances, insects, and vermin[2]. Also, flooding and wind affect cleanliness of the areas around the pens. Observation during recording at the site revealed nine storage pens that had refuse remaining after pickup by the municipal service as the result of refuse not being stored in plastic bags. Because of this condition, site personnel must clean up refuse and place in bags so that the city service crew will pick up the refuse on the next service day.

Site Appearance -

The pens are 8 ft x 8 ft x 8 ft redwood on concrete slabs. The pens are located next to parking areas and are easily detected. The chute-fed container is located in a special room under the building and is completely out of sight.

Environmental Considerations -

Deodorizer is used during pen cleanups, but odor still develops on hot days causing insect nuisances, particularly flies and yellowjackets. The pens in the single-family areas of the site appear free from odors and insects because the refuse is conscientiously placed in plastic bags. Pens in the multifamily areas contained spilled refuse which is not picked up by the municipal service and causes odor and insect problems. There are no apparent sanitation problems. Collection activities produce noises from engines, equipment operation, and particularly truck brakes.

Results

The results are presented as the advantages and disadvantages of the system in economics, effectiveness, efficiency, and environmental aspects.

Economic Advantages -

The site is charged a sanitary fee (includes a fee for refuse collection and disposal) by the city regardless of whether municipal trash service is used or not; therefore, it is economically advantageous for the site to make use of the city service where possible. The system could be more cost effective if a method could be devised whereby the city would service the entire site. A telephone conversation with personnel in the city utilities department indicates that the city could collect the refuse for the MFMR building so long as a suitable enclosure were provided and the refuse were placed in bags for pickup by collection personnel. The costs could also be reduced by not allowing storage of refuse in the pens by requiring residents to store refuse in their homes until the night before refuse pickup day. Since the resident must use plastic bags, storage in his home would influence proper closure of the bags and less exposure to the elements of weather and animals.

Economic Disadvantages -

Two pickup services are required, municipal for the single-family and low-rise buildings, and private service for the medium-rise building and the clubhouse. The municipal service will only pick up trash that has been placed into plastic bags and stored in the pens. Bulky waste items are picked up by site maintenance personnel and are disposed at the clubhouse dumpster-type container which, in effect, is an extra pickup service in terms of site labor. The private service must make three pickups per week for the medium rise and clubhouse buildings.

Effectiveness, Advantages -

If the site used all the storage pens, only one pickup per week would be required for all dwelling units. The residents must place refuse into plastic bags and then into the pens which then makes it easy for the municipal service to pick up the refuse.

Effectiveness, Disadvantages -

Residents must purchase plastic bags due to municipal requirements. The refuse is not protected from the weather in the pens. The chute in the medium-rise backs up with refuse necessitating cleanout every time the container is dumped. The chute problem is caused by improper design considerations (see Figure 2).

Efficiency, Advantages -

The pens provide concentrated storage and provide for fast pickup. The refuse removed per man-minute of labor is about

0.4 cu yd per man-minute of labor including all nonproductive time. For the entire site, productive man-time was 125 man-hours per year of the 214 man-hours used per year in refuse collection. Productive man-time was 65 percent of total labor used collecting refuse.

Efficiency, Disadvantages -

The municipal service will not pick up any refuse not stored in plastic bags. The manual pickup by the city incurs a high nonproductive rate with 35 percent of the active collection time spent waiting. The waiting time is caused by the truck driver waiting in the cab of the packer truck during pickup of refuse by the two helpers. The driver spend 73 percent of his time waiting (51 minutes out of 70 minutes on site). The helpers spend 14 percent of their time waiting during packing cycles of the truck (20 man-minutes out of 140 man-minutes while on site). In addition to collection man-time, site maintenance personnel spend 968 man-hours per year at a cost of $4873 per year picking up bulky wastes, cleaning in and around the pens and containers, and maintaining the equipment.

Environmental Aspects, Advantages -

The site aesthetics are fine with the pens located next to parking areas. The aesthetics could be greatly improved by planting shrubbery around the pens.

Environmental Aspects, Disadvantages -

The pens are noticeable throughout the site. The containers are particularly noticeable. Pens in the multifamily areas of the site have odors and attract flies and other insects. A resident survey[2] indicates problems with animals and insects at the site.

The pens have open tops and are subject to the effects of weather. By restricting residents to placing refuse in the pen the day before pickup, much of the weather effects would be minimized.

KALAMAZOO, MICHIGAN

The Kalamazoo site was visited on September 18, 19, and 20, 1973. The refuse management system consists of 16 screw type Model TM-200 Compackager compactors, each located for use by several residences, one chute-fed hydraulic-type compactor in the MFMR building, and two 4-cu yd containers in the parking lot opposite the community center. The compactors are serviced daily by site personnel who move refuse to the two 4-cu yd containers which are serviced twice a week by a private contractor. The compactors, the on-site collection, and the private contract containers and collection are shown in Figures 5,6, and 7. The site arrangement is shown in Figure 8. The site demographic and other data are given in Table 8.

Refuse System Description

SFA, SFD, and MFLR residents of the Kalamazoo site take their refuse to centrally located compactors for disposal. Keys are provided to residents for operating the compactors. Residents of the MFMR building place their refuse in a chute which feeds an automatically actuated hydraulic compactor on the bottom floor of the building. Each day, two men collect refuse from the compactors, replace plastic liners in the compactor, place refuse in a two and one-half ton dump truck, and dispose of the refuse in two 4-cu yd containers near the service building on the site. A private service contractor empties the containers twice a week into a top loading packer truck which requires only a driver for operation.

SFA, SFD, and MFLR residents are asked to separate glass items from refuse and place in barrels which are provided next to compactors. The MFMR residents are asked to separate glass items and newspapers from refuse and place in the chute charging rooms on each floor of the building. Glass is separated because it breaks during compaction and may injure collection personnel by puncturing the bags when lifted from the underside. Newspaper is not placed in the trash chute because of potential clogging at the lower end of the chute. Site personnel collect glass items and newspapers from each floor of the MFMR building. The separated items are not recycled to obtain revenue, probably because the total amounts are small and storage would be a problem.

Each day, plastic bags are replaced in each compactor, and disinfectant is sprayed around the compactor units. The bags are large size, 54" x 54", and heavy duty, 0.004 in. thick. Bags are carried by the site pickup crew each day. In addition to disinfectant spray, a private service is contracted to provide vermin control at each compactor. The control consists of bait boxes at each compactor area.

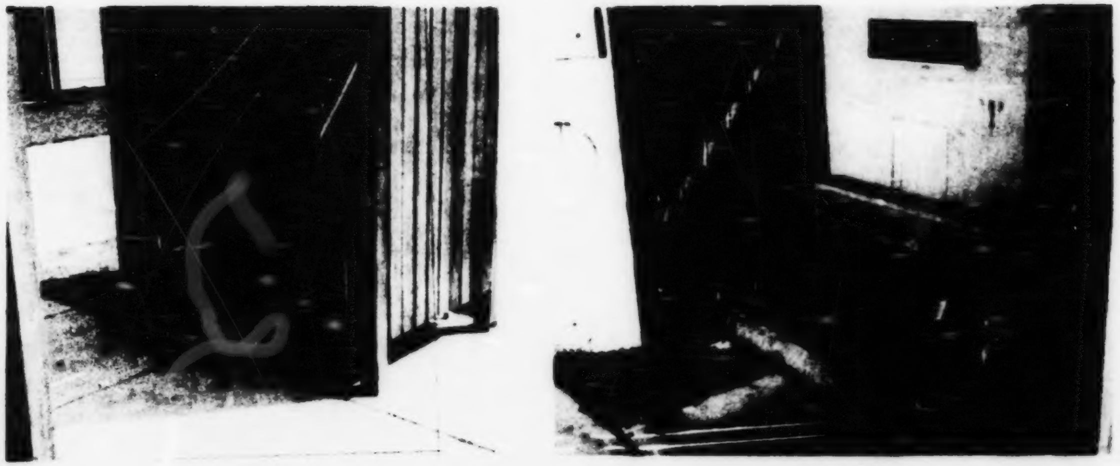


FIGURE 5. Typical of sixteen compactors in covered pens located around Kalamazoo, Michigan site. Note that the compactors have not been actuated after refuse insertion.

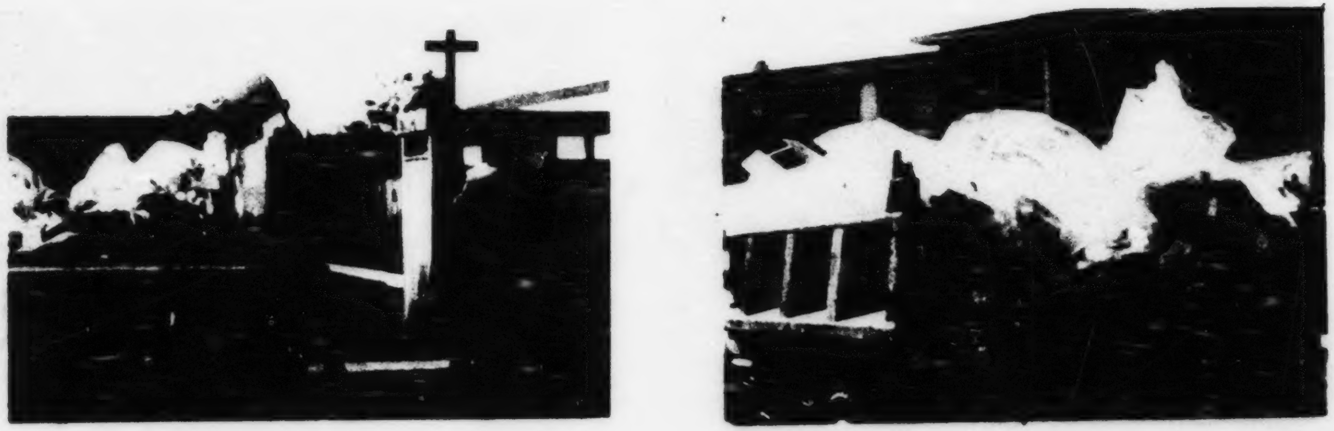


FIGURE 6. On-site refuse collection at Kalamazoo, Michigan.
Note the use of a barrel for disposal of glass by residents in the left photograph.

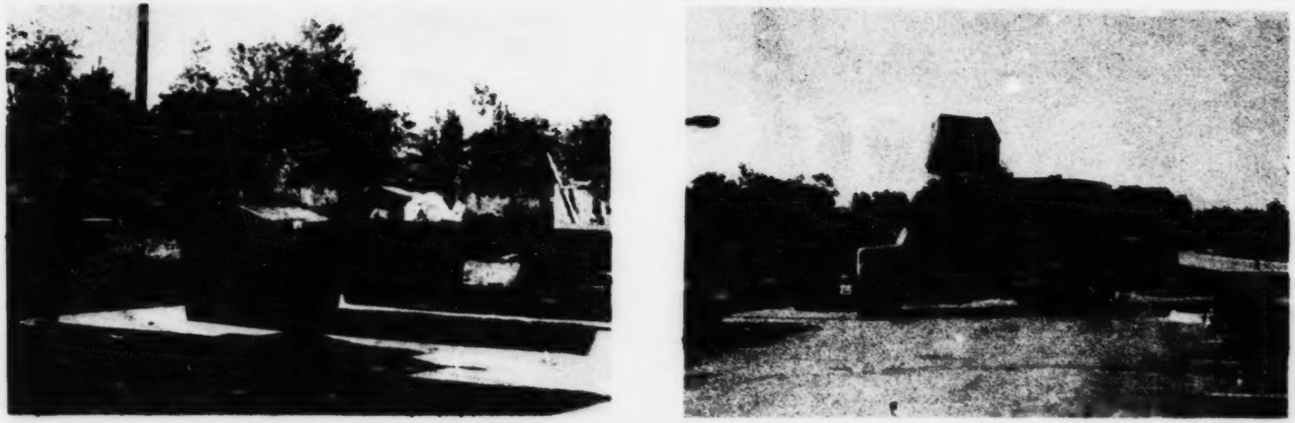
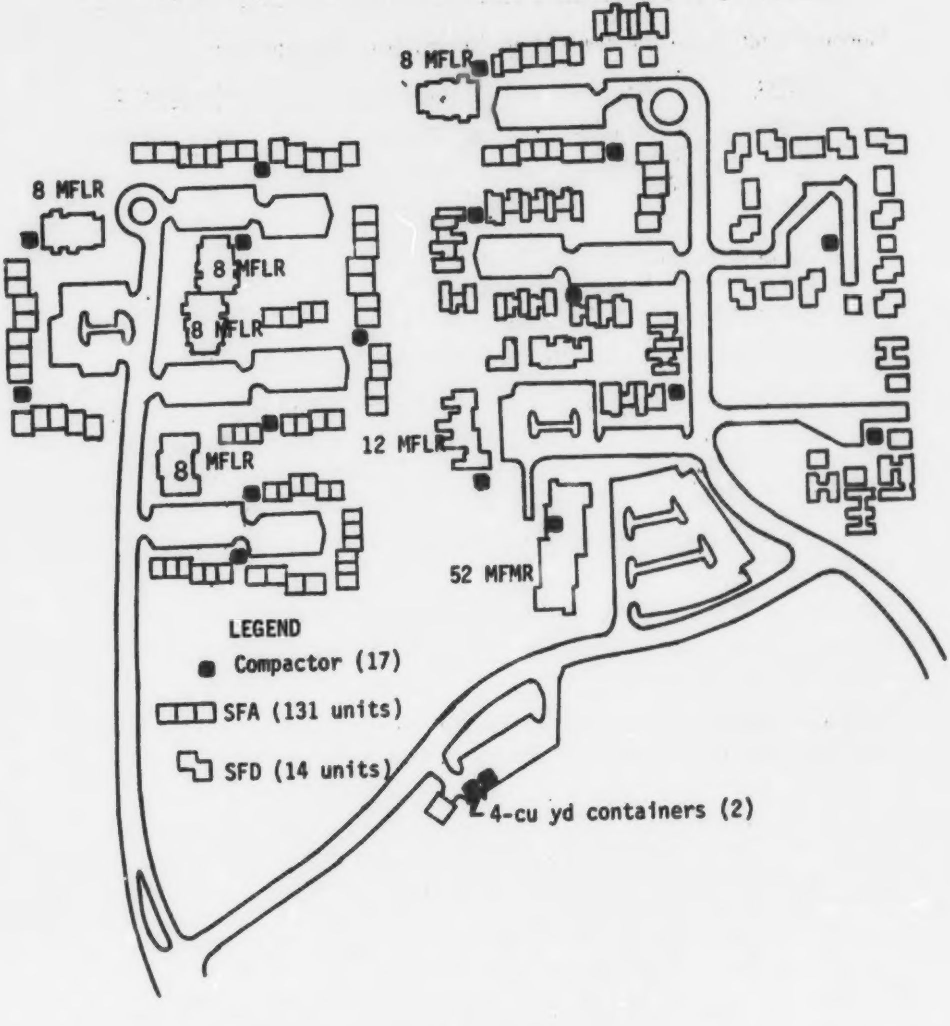


FIGURE 7. Refuse storage in 4-cu yd containers and collection by a top-loading packer truck at Kalamazoo, Michigan.


8 MFLR
8 MFLR
8 MFLR
8 MFLR
8 MFLR
12 MFLR
52 MFMR
LEGEND
● Compactor (17)
SFA (131 units)
SFD (14 units)
4-cu yd containers (2)

NOTE: Quantity of units other than SFA or SFD proceeds type of housing unit (e.g., 8 MFLR is 8 units in a MFLR building).

FIGURE 8. Kalamazoo Operation Breakthrough site arrangement showing location of compactors

Table 8. DEMOGRAPHIC AND SOLID WASTE SYSTEM DESCRIPTIVE DATA FOR THE KALAMAZOO OPERATION BREAKTHROUGH SITE

Number and Type of Dwelling Units and Occupancy:

Type	No.	Vacancies	Residents
SFA	127 units	8 units	414 people
SFD	14	0	56
MFLR	52	9	105
MFMR	52	0	56

Number occupied: 228 units
Number residents: 631 people
Site area: 33.8 acres

Distribution of Units to Each Refuse Service Point:

Number and Type	Compactors
14 SFD	2 Model TM-200 Compackager
183 SFA/MFLR	14 Model TM-200 Compackager
52 MFMR	1 Hydraulic Compactor

All refuse is collected daily and stored in two 4-cu yd containers.

One 2-1/2 ton dump truck is used for collection.

Plastic bags, 54"x54"x.004" clear polyethylene, are used for collection.

Average number of units per service = 13.4
Average number of people per service = 37.1

Based on observation of refuse collection and pickup for one day at the site, approximately 77 cu yd of loose refuse are collected per week, or approximately 4000 cu yd per year. The refuse load was estimated from the collected amounts of compacted and uncompacted refuse with compacted refuse concentrated at a ratio of eight parts loose to one part compacted.

A private contractor services two 4-cu yd containers twice a week utilizing a top loading packer truck. The containers are serviced each Monday and Thursday. An average load on a pickup day is 38.5 cu yd of loose refuse. The capacity of the truck is 30 cu yds packed; therefore, the site does not fill the truck. The truck services other locations before and after servicing the site.

Economics Analysis

The economic data are tabulated in Table 9 in general form. The private service contract for the site is less than 10

Table 9. COST OF REFUSE COLLECTION AND DISPOSAL AT THE KALAMAZOO OPERATION BREAKTHROUGH SITE

	Initial Costs	Multiplier[a]	Oct. 1975 Costs	Carrying Charge[b]	Annual Costs	Cost/DU/ Yr (295)[c]	Cost/Cap./ Yr (1038)[c]	Cost/Cu Yd/ Yr(5900 Cu Yd/Yr)[c]
Capital Costs								
Compactors (10-yr life)	$18,580	1.1673	$21,688	0.146	$3,166			
Compactor keys, replacement[d]	14	1.1673	16	NA	16			
Compactor shelters (7-1/2-yr life)	2,363	1.1673	2,758	0.179	494			
Chute, Dillon Bldg. (40-yr life)	1,080	1.1673	1,261	0.079	100			
Truck (5-yr life)[e]	1,235	1.1673	1,442	0.247	356			
					$4,132	$14.00	$3.98	$0.70
Recurring Costs								
Insurance and licenses[f]	$ 52	1.1673	$ 61	NA	$ 61	$ 0.21	$0.06	$0.01
Operation and Maintenance Costs								
Labor, service, site[g]	$ 3,506	1.1908	$ 4,175	NA	$4,175			
Labor, supervisory, site[h]	1,278	1.1908	1,522	NA	1,522			
Fuel, lubricants, parts for truck	429	1.1673	501	NA	501			
Plastic bags[i]	2,594	1.1673	3,028	NA	3,028			
Pest control contract[j]	160	1.1908	191	NA	191			
Deodorant[k]	90	1.1673	105	NA	105			
Private contract service[l]	1,140	1.1673	1,331	NA	1,331			
Compactor repair materials[m]	19	1.1673	22	NA	22			
Compactor shelter materials[m]	3	1.1673	4	NA	4			
					$10,879	$36.88	$10.48	$1.84
Total Annual Costs					$15,072 per year	$51.09 per DU per year	$14.52 per capita per year	$2.55 per cu yd

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a - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.

b - The carrying charge is interest plus sinking fund factor. See Section I for explanation.

c - Occupancy was 232 dwelling units out of 245 dwelling units on the site. The number of residents and the observed refuse collected are multiplied by 245/232 to adjust to total site occupancy (September 1973 data).

d - Annual charge due to losses.

e - $5374, 5-year life, used 52.5 minutes per day, utilized 23 percent of time for refuse collection (September 1973 data).

f - Utilized 23 percent of time for refuse collection, recurring costs are $224.

g - 1,169 man-hours per year at $3.00 per hour including fringe benefits (September 1973 data).

h - 365 man-hours per year at $3.50 per hour including fringe benefits (September 1973 data).

i - 22 bags per day for 365 days at $0.323 per bag (September 1973 costs).

j - Costs are $10 per year per compactor (September 1973 costs).

k - Estimated as $7.50 per month (September 1973 costs).

l - Contract to service the container twice a week at $95 per month.

m - Estimated as one percent of annual capital costs.

percent of the estimated annual costs; however, the cost elements may be estimated from data obtained from discussions with the service contractor and apportioned to obtain the total price to the site. The apportionment of cost is based upon the contractor's time on the site of 6.5 minutes per pickup day. The apportioned costs are shown in Table 10 and include profit to the private contractor.

Table 10. APPORTIONED COSTS TO THE KALAMAZOO SITE FOR SEGMENTS OF COSTS OF THE PRIVATE SERVICE CONTRACTOR

	Annual Costs	Apportionment Factor	October 1975 Annual Costs to Site
Capital Costs			
Truck	$ 44	6%	$ 80
Containers (2)	51	7%	93
	$ 95	13%	$ 173
Recurring Costs			
Insurance, licenses, taxes	$ 7	1%	$ 13
Operation & Maintenance Costs			
Labor with 20% fringe benefits	$ 74	10%	$ 133
Supervisory costs	15	2%	27
Landfill costs	529	72%	958
Operating costs	15	2%	27
	$633	86%	$1,145
Total Annual Site Costs	$735	100%	$1,331

NOTE: Costs to site include contractor profit.

The expense associated with each element of refuse collection and disposal is shown in Table 11. The resulting costs are $14.52 per capita per year which is $0.48 higher than the national survey results of $12.08 per capita per year. Labor, plastic bags, and the compactor costs account for 83 percent of the total costs for refuse collection at the site. The single major cost item is for labor at 39 percent of total annual costs.

Table 11. COMBINED SEGMENTS OF ANNUAL EXPENSES FOR REFUSE COLLECTION AND DISPOSAL AT THE KALAMAZOO SITE (OCTOBER 1975 BASIS)

	Private	Site	Segment Total	Percent of Annual Total
Capital Costs				
Truck	$ 80	$ 356	$ 436	3%
Containers	93		93	1
Compactors, keys, shelters		3,676	3,676	24
Refuse chute		100	100	1
	$ 173	$ 4,132	$ 4,305	29%
Recurring Costs				
Insurance, licenses, taxes	$ 13	$ 61	$ 74	-
Operation & Maintenance Costs				
Labor	$ 160	$ 5,697	$ 5,857	39
Operating, maintenance	27	823	850	6
Landfill fees	958		958	6
Plastic bags		3,028	3,028	20
	$1,145	$ 9,548	$10,693	71%
Totals	$1,331	$13,741		100%
Annual Total	$15,072			

Technical Analysis

The collection and disposal of refuse at the Kalamazoo Operation Breakthrough site was observed for two days. Based on estimated volume of observed refuse and discussions with site personnel, the estimated refuse collected is 77 cu yd per week for 232 occupied dwelling units. Expanding for full occupancy (245 units), the refuse collection load is about 81 cu yd per week or about 4200 cu yd per year. The technical data for refuse collection and disposal are summarized in Table 12 including distance travelled, number of stops, dwelling units serviced, crew size, refuse collected, estimated volume, elapsed time, and labor time expenditures. Table 12 includes actual observed data for the 95 percent occupied site. The nonproductive time is considered as all waiting and packing time and is 17 percent of the total labor spent in refuse collection activities.

Equipment Performance -

Suitability - The equipment (compactors) are capable of 10:1 volume reduction of trash. A 10:1 reduction in volume should reduce the weekly loose refuse volume to 7.7 cu yd (compacted) which could be easily stored in the two 4-cu yd containers. Since there are 17 compactors, the weekly refuse volume for each compactor should average about 0.45 cu yd.

Each compactor holds 0.165 cu yd (compacted); therefore, pickups throughout the site could be reduced to three pickups per compactor per week. The MFMR building may require four pickups per week. This would reduce pickup labor costs, reduce plastic bag usage, reduce on-site truck travel, and reduce the number of off-site pickup and disposal trips by the private contractor. The resultant savings would be $0.26 per cu yd of loose refuse generated on the site, as shown in Table 13. The annual costs of the observed system and of the system if operated properly are:

	As-Observed	If Properly Operated
Total Annual Costs	$15,072	$9,359
Cost/Dwelling Unit/Yr	$51.09	$38.20
Cost/Capita/Yr	$14.52	$14.05
Cost/Cu Yd of Loose Refuse	$2.55	$2.29

Table 12. OBSERVED REFUSE COLLECTION ACTIVITIES AT THE KALAMAZOO SITE FOR ONE PICKUP AND ONE YEAR WITH ANALYTICAL RESULTS

							Time Elements				
Service	Distance Travelled	No. of Stops	No. of Units	Crew Size	Items Collected	Estimated Volume	Elapsed	Riding	Walking/ Handling	Waiting/ Packing	Total Mantime
Site (One pickup/day)	1.8 miles	17	232	2	16 cartons glass 20 plastic bags 4 paper bags several paper boxes	11 cu yd (loose)	4950 sec.	2675 man-sec.	5583 man-sec.	1642[a] man-sec.	9900 man-sec.
Private	0.2 mile	1	232	1	2 containers	37.5 cu yd(loose)	390 sec.	20 man-sec.	-	370 man-sec. (dumping/ packing)	390 man-sec.
Total Per Year	678 miles per yr	6309 stops/yr	232 units served	-	-	4000 cu yd/yr	513 hr/yr	272 man-hr/ yr	566 man-hr/ yr	177 man-hr/ yr	1015 man-hr/ yr

Analytical Results

Average distance per stop (18):	0.1 miles per stop
Average labor per stop (18):	9.7 man-minutes per stop
Average dwelling unit density per stop (17):	13.6 dwelling units per stop
Average labor per cu yd:	15.2 man-minutes per cu yd
Riding:	4.1 man-minutes per cu yd
Walking/Handling:	8.5 man-minutes per cu yd
Waiting/Packing:	2.6 man-minutes per cu yd

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[a] 1642 man-seconds made up of 416 man-seconds operating compactors and 1226 man-seconds waiting time.

Table 13. COSTS FOR KALAMAZOO REFUSE COLLECTION ASSUMING THE COMPACTORS WERE PROPERLY UTILIZED (OCTOBER 1975)

	Private	Site	Segment Total	Percent of Annual Total
Capital Costs				
Truck	$ 40	$ 152	$ 192	2%
Containers	93		93	1
Compactors, keys, shelters		3,676	3,676	39
Refuse chute		100	100	1
	$ 133	$3,928	$4,061	43%
Recurring Costs				
Insurance, licenses	$ 7	$ 26	$ 33	1
Operation & Maintenance Costs				
Labor	$ 80	$2,441	$2,521	27
Operating, maintenance	14	474	488	5
Landfill fees	958		958	10
Plastic bags		1,298	1,298	14
	$1,052	$4,213	$5,265	56%
Totals	$1,192	$8,167		
Annual Total	$9,359			100%

Cost per du (245)	$38.20 per du per year
Cost per capita (666)	$14.05 per cap. per year
Cost per cu yd (4200)	$2.29 per cu yd

Effectiveness - The effectiveness can be measured as the relative degree to which the system is performing as designed. Assuming \$2.29 per cu yd was a suitable design objective, the system could be stated to have achieved the following effectiveness:

$$\left[1 - \left(\frac{2.55-2.29}{2.29}\right)\right] \times 100 = 89 \text{ percent effectiveness}$$

Under these assumptions, the system has performed nearly as well as intended.

Compactor performance could not be assessed because records of repairs were not available. On the date that data were gathered, two compactors were in a failed condition. The switch did not work on one compactor and the other compactor had sustained structural damage which required welding to effect repair.

Resident Acceptance - Residents had only cycled three of 16 compactors on the morning of the day that pickup data were recorded (8:30 a.m.). The automatic actuator on the MFMR compactor was not functioning. Between 3 and 3:30 p.m. on the same day, a check of all compactors revealed that two had been cycled out of 17. The observed data indicate that residents carry refuse to the compactor, but do not actuate the units. The observed data are listed below with the related refuse content also shown. The data indicate that residents neither realize the potential of the compactors nor properly utilize the compactors. The accumulation of refuse at each compactor location caused site management to initiate daily pickups. Some residents expressed concern about the cost of the refuse service. Site management has sent letters to each resident requesting that they actuate the compactors or possibly be faced with extra fees to pay for the daily collection service.

Compactor Chamber Loading	Compactor Not Cycled	Compactor Cycled
Full	4	
3/4 full	1	1
1/2 full	3	1
1/4 full	5	
Empty	2	

A separate report presents the results of a survey of residents attitudes with respect to refuse removal at the

Kalamazoo site. The results of that report indicate that MFMR residents have no problems, that single-family homes experience overloading of facilities and lack of protection from pets, and that MFLR apartment residents experience overloading of facilities. Only two respondents to the survey reported trouble with the compactors. The details of the survey are included in Reference 2. Observations during the three-day site visit resulted in two instances of pet nuisance and both instances were the result of not placing refuse inside the compactors.

Site Appearance -

The compactor shelters blend in with the site even though they are noticeable. Strewn refuse was evident at one location where a pet was observed emptying several bags of refuse which had been placed on the ground next to the compactor. Overflow was evident at five compactors which had not been actuated (all five were in satisfactory condition). Bags of refuse and boxes placed next to the compactors create site-appearance nuisances.

Environmental Considerations -

The refuse left outside detracts from appearance and could cause insect problems, though no insects were observed. The use of deodorizer on a daily basis effectively eliminates odors. No sanitary problems appeared to exist. Very little noise is created by the compactors or the collection activity, and no complaints about noise had been received by the site management.

A safety problem exists with the use of the compactors. When handling bags of refuse, shattered glass has penetrated the bags and caused several instances of severe cuts to hands and arms requiring hospital emergency treatment. The solution at the site is segregation of glass from refuse. Glass is placed in a container next to the compactor.

Results

The results are presented as the advantages and disadvantages of the Kalamazoo refuse collection system in economics, effectiveness, efficiency, and environmental aspects.

Economic Advantages -

If properly operated, the system would cost $2.29 per cu yd of refuse which is reasonable. Lower costs might be achieved if landfill fees could be saved through utilization of the refuse compactors. Assuming proper compaction, the site could haul the refuse to the landfill in the truck owned by the site and save most of the costs of the private service contractor.

Economic Disadvantages -

Residents do not actuate the compactors which has resulted in refuse overflows of the compactors and in daily collection at the site. The use of compactors has not been a benefit to the site economics. Excessive costs are incurred for pickup labor, plastic bags, on-site hauling, and disposal costs. The costs observed are $2.55 per cu yd of loose refuse. Costs could be reduced to $2.29 per cu yd if the compactors were properly utilized thus allowing reduction of pickups from seven to three per week by site maintenance personnel and reduction from two to one pickups per week by the private service contractor.

Effectiveness, Advantages -

Refuse is removed. If properly operated, the system could reduce refuse collection and disposal costs through elimination of four pickups per week by site personnel.

Effectiveness, Disadvantages -

On a cost basis, the effectiveness is about 89 percent; that is, the system costs are 11 percent higher than they could be if the system were properly utilized. The requirement for resident participation is not effective for the site.

Residents do not start the compactors. Trash is placed in side the compactors if the chamber is not full, but the compactors are not started. Two solutions are possible. Either place the key lock on the chamber handle and have the machine automatically cvcle when the door is closed or place a timer on the compactors so that they will actuate over a set interval of time. The timer will still require a key lock on the chamber door to preclude entry by children.

Efficiency, Advantages -

None as currently utilized. Collection labor requirements could be greatly reduced and efficiency could be greatly increased if residents actuated the compactors. The utilization of labor could become 95 percent or higher if collection personnel did not have to actuate the compactors.

Efficiency, Disadvantages -

The personnel utilization is 83 percent due to personnel having to actuate compactors. Fuel, plastic bags, and labor could be conserved if the residents properly utilized the compactors. Because of improper compactor utilization, much refuse handling is required at the site by residents, site personnel loading and unloading, and private contractor pickup service loading.

Environmental Considerations -

Advantages - The site is free from odors, insects, and vermin. The aesthetics are good. If compactors were properly used, landfill volume, disposal fees, and refuse handling could be reduced.

Environmental Considerations -

Disadvantages - Refuse is left on the ground outside of compactors and increases the possibility of spillage and of attraction of pets, insects, and vermin. A greater volume of refuse must be handled than should be the case if the compactors were properly utilized. The system was a hazard to collectors handling bags with broken glass inside. Separation of glass from refuse has become necessary to preclude handling hazards. It is recommended that a metal, hinged carrying "caddy" or similar device be devised for handling compacted packages which are removed for disposal and, thereby, eliminate segregation of glass from the refuse.

MACON, GEORGIA

The Macon site was visited on October 1, 2, and 3, 1973. The refuse management system consists of twenty-four 2-cu yd containers located throughout the SFA, SFD, and MFLR dwelling unit areas of the site. A chute-fed compactor with two side compaction 2-cu yd containers is utilized in the MFM/HR building. Redwood pens enclose the containers on three sides. The chute-fed compactor and containers are located in a room in the base of the MFM/HR building. One container is located at the site maintenance building. The compactor containers are serviced three times a week and the other containers are serviced twice a week by a private contractor. Figures 9 and 10 are photographs of container locations and the chute-fed compactor and container. The site arrangement is shown in Figure 11. The site demographic and other data are given in Table 14.

Table 14. DEMOGRAPHIC AND SOLID WASTE SYSTEM DATA FOR THE MACON, GEORGIA, OPERATION BREAKTHROUGH SITE

Number and Types of Dwelling Units and Occupancy:

Type	No. Units	Occupancy Units	Occupancy People
SFA	159	134	437
SFD	6	4	17
MFLR	42	35	60
MFM/HR	80	79	136
	287	252	650

Site Area: 50 acres

Distribution of Units and Refuse Containers:

Number and Type of Units	Containers (2 cu yd each)
30 SFA/SFD	5
177 SFA/MFLR	18
80 MFM/HR	2 (fitted to compactor)
Maintenance Building	1
	26

Adjusted Occupancy: (650)x(287)/(252) = 740
Average Number of Units per Container = 11

Refuse System Description

SFA, SFD, and MFLR residents of the Macon site place refuse in the containers located next to their homes. MFM/HR residents place refuse in the refuse chute charging stations located on each floor which feed a compactor at the base of the chute. Twenty-two containers are located convenient to residential parking areas and are serviced by a private contractor twice each week. The same contractor services two compactor containers three times each week. When a container is full, site personnel replace the container with an empty

FIGURE 9. Two typical containers and pen locations at the Macon site. One is center left next to the trees. The other is just to the right of the basketball goal.

FIGURE 10. The Chute-fed compactor and container in the MFM/HR building at the Macon site.

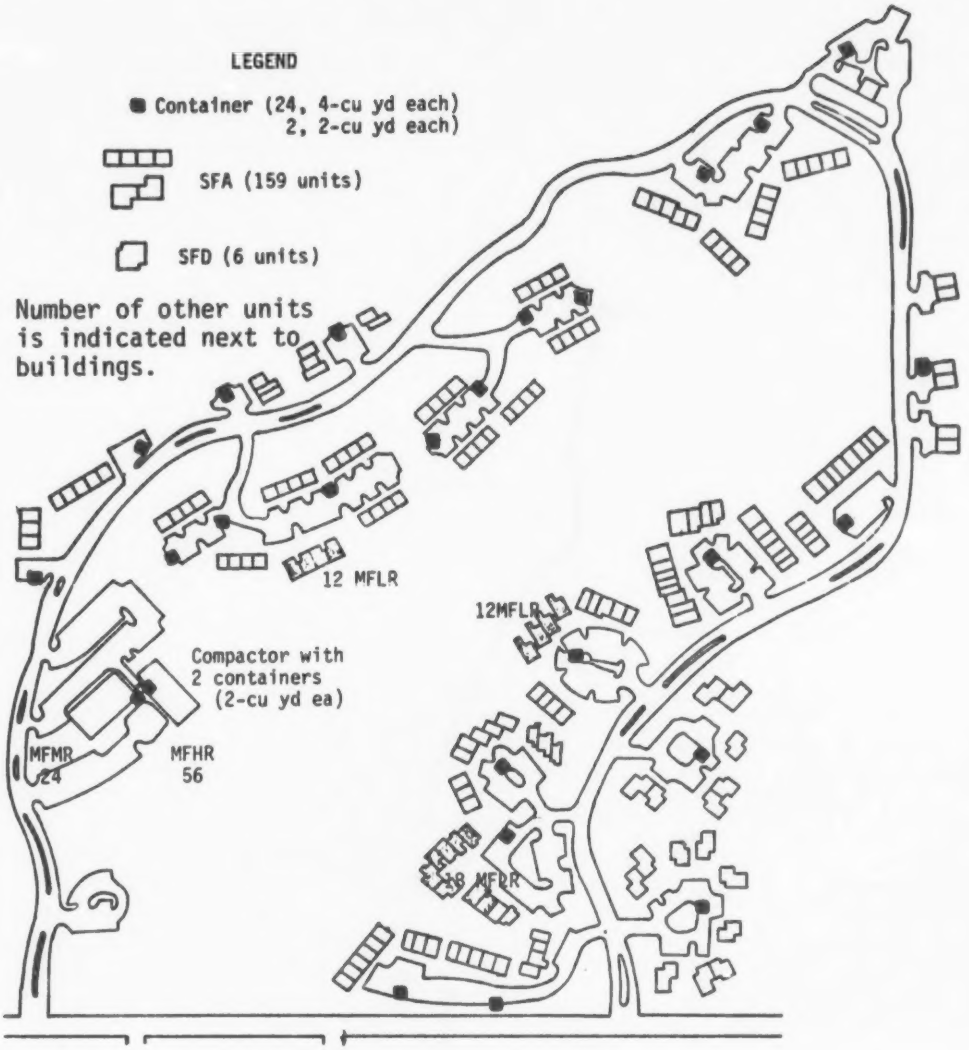
LEGEND
Container (24, 4-cu yd each)
2, 2-cu yd each)
SFA (159 units)
SFD (6 units)
Number of other units is indicated next to buildings.
12 MFLR
12MFLR
Compactor with 2 containers (2-cu yd ea)
MFMR 24
MFHR 56
18 MFLR

FIGURE 11. Macon Operation Breakthrough Site arrangement of containers

by rolling the containers around; Figure 12 shows a full compactor container with the empty attached to the compactor. All site containers are emptied by a front to overhead loading packer truck with a driver performing all work functions. The driver deodorizes each container using a truck mounted sprayer. The packer truck is shown in Figure 13. Based on observation of refuse collection for two days at the site, approximately 36 cu yd of loose refuse are collected per week from the MFM/HR building and about 65 cu yd of loose refuse per week are collected from the SFA, SFD, and MFLR units. The estimated annual refuse load is 5250 cu yd of loose refuse. The MFM/HR was calculated on the basis of four to one compaction units. Refuse is hauled to a landfill when the truck is full. The capacity of the truck is 30 cu yd compacted. The truck services other residential areas before and after visiting the site. Cleanup around containers is performed by site personnel who use a small tractor and trailer to clean up around the site.

Economic Analysis

The descriptive economic data for the refuse system at the Macon site is given in general form in Table 15. The costs of site labor and the private service contract are the two highest single cost items at the site. The private service contractor would not furnish data relative to the elemental costs that make up the total site costs. Based on observed data, the cost elements are estimated and are shown in Table 16. Contractor labor data is based upon being on the site a total of 271.4 hours per year. Landfill fees are five dollars per load. The driver salary is based on five dollars per hour. The expense associated with each element of refuse collection and disposal for the Macon site is shown in Table 17.

The economic results can be compared with the adjusted national survey results[1] for community solid wastes management costs. The site costs are $28.52 per capita per year compared to $12.08 per capita per year adjusted from the national survey (see Section I for October 1975 adjusted basis). Labor and packer truck costs account for 60 percent of the total costs for refuse collection at the site. Site capital costs are $4.24 per capita per year which is higher than the $3.04 per capita per year from the adjusted 1968 survey. Operating and maintenance costs are $24.28 per capita per year which is much higher than the $9.04 per capita per year costs from the adjusted 1968 survey. The private service contract accounts for 55 percent of all costs of refuse disposal.

FIGURE 12. One compactor container is replaced with empty between service days at the MFM/HR at the Macon site.

FIGURE 13. Private contractor top-loading packer truck used to empty containers at the Macon site.

Table 15. COST OF REFUSE COLLECTION AND DISPOSAL AT THE MACON OPERATION BREAKTHROUGH SITE

	Initial Costs	Multi-plier[a]	Oct. 1975 Costs	Carrying Charge[b]	Annual Costs	Cost per DU/Yr (287)[c]	Cost per Cap./Yr (740)[c]	Cost per Cu Yd/Yr (6000 cu yr/yr)[c]
Capital Costs								
Refuse chute (40-yr life)	$9,000	1.1707	$10,536	0.079	$ 832			
Compactor (10-yr life)	5,000	1.1707	5,854	0.146	855			
Container pens (7.5-yr life)[d]	4,300	1.1707	5,034	0.179	901			
Tractor & trailer (10-yr life)	3,200	1.1707	3,746	0.146	547			
					$3,135	$10.92	$4.24	$0.52
Recurring Costs	0	0	0	0	0	0	0	0
Operating and Maintenance Costs								
Labor, site[e]	$3,650	1.1902	$ 4,344	NA	$4,344			
Labor, site, supervisor[f]	1,268	1.1902	1,509	NA	1,509			
Fuels and lubricants[g]	390	1.1707	457	NA	457			
Private service contract[h]	9,960	1.1707	11,660	NA	11,660			
					$17,970	$62.61	$24.28	$3.00
Total Annual Costs					$21,105 per year	$73.53 per DU per year	$28.52 per cap. per year	$3.52 per cu yd

a - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.

b - The carrying charge is interest rate plus sinking fund factor. See Section I for explanation.

c - Occupancy was 252 dwelling units. The number of residents and observed refuse collected are multiplied by 287/252 to adjust to total site occupancy of 287 units (October 1973 data).

d - The pen at the maintenance building is not enclosed. Cost shown is for 23 pens.

e - 25 man-hours/week, $2.34/hour plus 20% fringe benefits (October 1973 data).

f - 4 man-hours/week, $5.08/hour, plus 20% fringe benefits (October 1973 data).

g - $7.50/week for fuel, lubricants, maintenance (October 1973 data).

h - $830 per month for the site (October 1973 data).

Table 16. ESTIMATED COSTS TO THE MACON SITE FOR SEGMENTS OF COSTS OF THE PRIVATE SERVICE CONTRACTOR (OCTOBER 1975)

	Estimated Annual Costs[h]	Percent of Total Annual Cost	Estimated Site Costs[g]
Capital Costs			
Truck[a] $23,000 (5 yr)[a]	$1,056	19%	$ 2,216
Containers (24)[b]	779	14	1,632
	$1,835	33%	$ 3,848
Recurring Costs			
Insurance, taxes, licenses	$ 937	17%	$ 1,982
Operating and Maintenance Costs			
Labor w/20% fringe benefits[c]	$1,938	35%	$ 4,081
Supervisory costs[d]	290	5	583
Landfill fees[e]	119	2	233
Operating costs[f]	403	8	933
	$2,750	50%	$ 5,830
Total Annual Costs	$5,522	100%	$11,660

---

a - Truck at $23,000 with five-year life.
b - Containers at $190 each, 10-year life.
c - Labor based on 211.4 hours per year on-site. Labor rate is $5/hour.
d - Supervisory costs based on 15% of labor.
e - $5 per load and the site contributes 20 loads per year.
f - Fuels, maintenance at $10/day.
g - Actual charge to site is $11,660 annually. Each line entry includes profit.
h - The estimated costs are based on data obtained from the service contractor and do not include profit. The costs to the site includes profit (see footnote g). Truck used 13 percent of year on the site.

Table 17. COMBINED SEGMENTS OF ANNUAL EXPENSE FOR REFUSE COLLECTION AND DISPOSAL AT THE MACON SITE (OCTOBER 1975 BASIS)

Cost Segments	Private	Site	Segment Total	Percent of Annual Total
Capital Costs				
Refuse chute		$ 832	$ 832	4%
Compactor		855	855	4
Container pens		901	901	4
Tractor and trailer		547	547	3
Truck	$2,216		2,216	10
Containers	1,632		1,632	8
	$3,848	$3,135	$ 6,983	33%
Recurring Costs				
Insurance, taxes, licenses	$1,982		$ 1,982	9%
Operation and Maintenance				
Labor	$4,664	$5,853	$10,517	50%
Operating and maintenance	933	457	1,390	7
Landfill fees	233		233	1
	$5,830	$6,310	$12,140	58%
Totals	$11,660	$9,445		
Annual Total	$21,105			100%

Technical Analysis

The collection and disposal of refuse at the Macon Operation Breakthrough site was observed for three days. Based on estimated volumes of observed refuse and discussions with site personnel, the estimated refuse collected is 101 cu yd per week, or about 5250 cu yd per year, for the 252 occupied residences. Expanding for full occupancy (287 units), the refuse collected per year is about 6000 cu yd. The technical data for refuse collection and disposal are summarized in Table 18 including distance traveled, number of stops, dwelling units serviced, crew size, refuse collected, estimated volume, elapsed time, and labor time expenditures. Table 18 includes actual observed data for the 88 percent occupied site. Nonproductive time is considered as all waiting and packing time and is 13 percent of the labor spent in refuse collection activities.

Equipment Performance -

Suitability - The compactor in the MFM/HR building was not operating satisfactorily. The refuse backs up the chute every day because of an off-centerline location of the compactor and lack of clearance between the chute opening and the chamber of the compactor. Figure 14 depicts the situation. Additionally, the automatic photoelectric actuator for the compactor does not function and the compactor requires manual operation several times a day. The resultant chute blockages require 30 minutes a day to clear. Chute blockage and cleanout is shown in Figure 15. As shown by the photograph, chute cleanout is not an easily performed task. An additional 15 minutes a day are required to clean the refuse room. Refuse chute cleanout requires 130 man-hours per year, and refuse room cleanup requires 65 man-hours per year. The refuse room cleanup is necessitated by refuse spillage out of the side of the compactor container when the containers are moved around the refuse room (see Figures 12 and 16).

The collection of refuse from the containers located around the site is complicated by lack of turning room and lack of adequate space for the truck to properly approach the container. Thirteen containers must be manually rolled out of the enclosures and positioned so that the truck can approach and empty the containers. After dumping, the driver pushes the containers back into the enclosures. The containers are equipped with wheels so that movement is possible. In sloped parking areas, the containers tend to roll downhill, and in two locations, container movement must be carefully

Table 18. OBSERVED REFUSE COLLECTION ACTIVITIES AT THE MACON SITE FOR ONE PICKUP AND ONE YEAR WITH ANALYTICAL RESULTS

Service	Distance Traveled	No. Stops	No. Units	Crew Size	Items Collected	Estimated Volume	Time Elements				
							Elapsed	Riding	Walking/ Handling	Waiting/ Packing	Total Man-time
Private:											
(a) 24 containers (twice/week)	2.3 mi.	24	173	1	24 containers	32.5 cu yd (loose)	6934 sec.	2624 man-sec	3466 man-sec	844 man-sec	6934 man-sec
(b) 2 containers (3 times/wk)	1.0 mi.	1	79	1	2 compactor containers	12 cu yd (loose)	1526 sec.	516 man-sec	890 man-sec	120 man-sec	1526 man-sec
Site (helping truck driver perform (b) above)			-	1	(b) above	(b) above	2065 sec.	0	1700 man-sec	365 man-sec	2065 man-sec
TOTAL/YEAR	395 mi.	2652 yr.	252	see above	2808 containers	5250 cu yd per yr	290 hours per yr	98 man-hrs per yr	212 man-hrs per yr	45 man-hrs per yr	355 man-hrs per yr

Analytical Results

Average distance per stop	0.1 miles per stop
Average labor per stop	8.0 man-minutes per stop
Average dwelling unit density per stop	4.9 dwelling units per stop
Average labor per cu yd	4.1 man-minutes per cu yd
Riding:	1.1 man-minutes per cu yd
Walking/Handling:	2.4 man-minutes per cu yd
Waiting/Packing:	0.5 man-minutes per cu yd

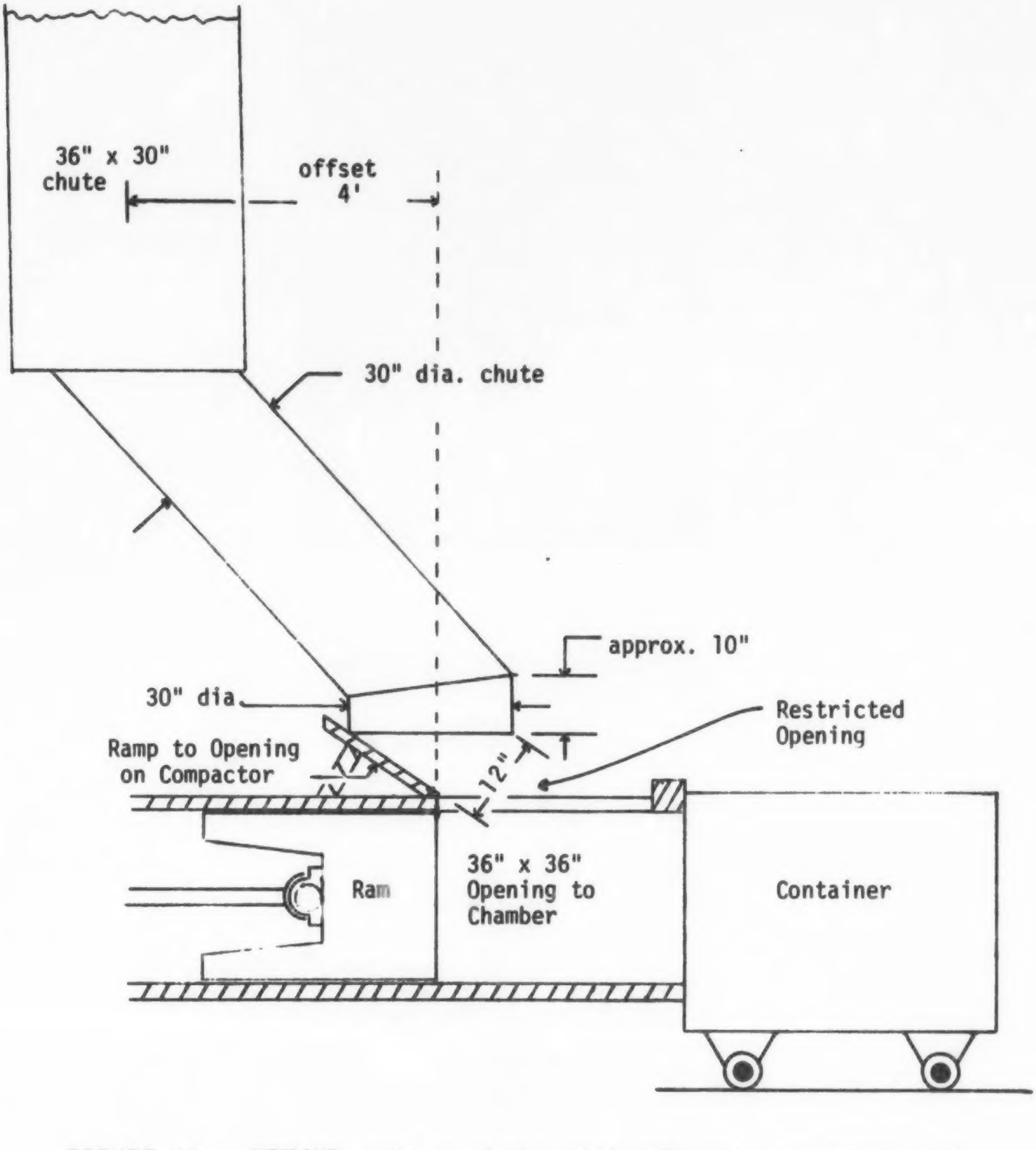
36" x 30"
chute
offset
4'
30" dia. chute
approx. 10"
30" dia
Restricted
Opening
Ramp to Opening
on Compactor
12"
36" x 36"
Opening to
Chamber
Ram
Container

FIGURE 14. MFM/HR refuse chute with off-set compactor and restricted opening at the chute-to-chamber interface which results in chute backups

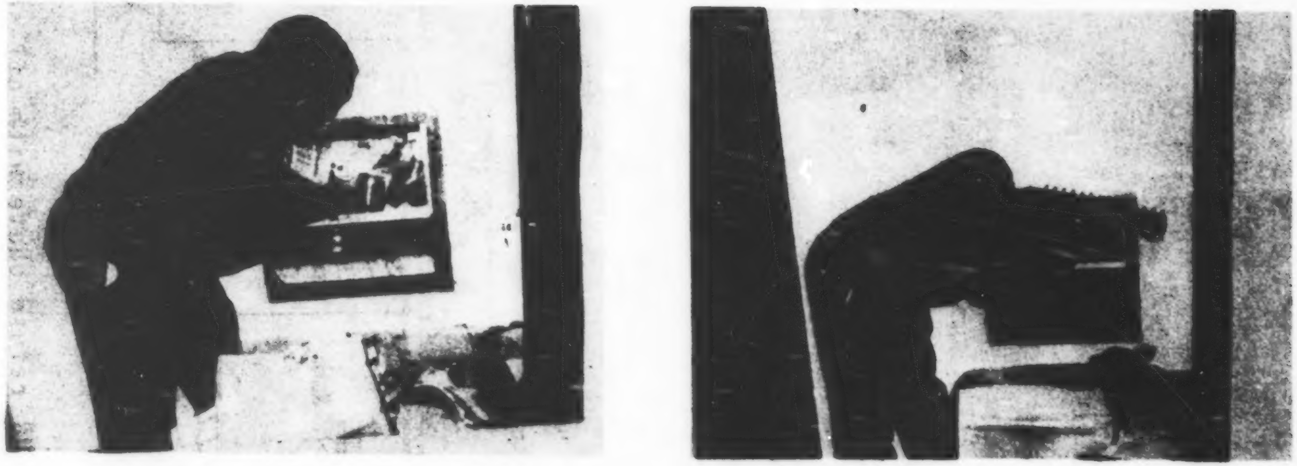

FIGURE 15. Refuse chute blockage at second floor of MFM/HR building at the Macon site. Chute was backed up to third floor.

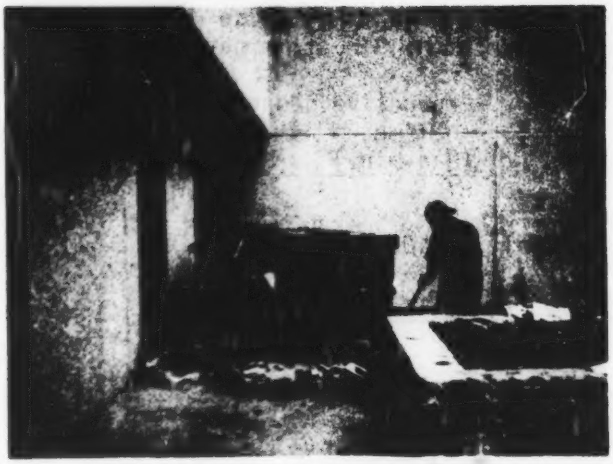

FIGURE 16. Refuse spills out of side opening of compactor containers in the MFM/HR building on the Macon site.

controlled to prevent rolling downhill into parked automobiles. The parking areas are not wide enough for the turning radius of the truck, which results in considerable jockeying of the truck to approach containers, turn around, and leave the parking area.

Effectiveness - The effectiveness is not as high as intended because of the refuse chute and compactor problems which require chute clean out, actuation of the compactor, and excessive refuse room cleanup. If the 195 man-hours required for chute and room cleanouts were subtracted from the data in Table 14, the reduction in costs are $651 per year. Also, 16 man-hours per year of waiting time is associated with the site personnel helping the private service contractor load the compactor containers. If the 211 man-hours were deleted, the reduction in costs are $705 per year or twelve cents per cubic yard of refuse. The effectiveness of the system, as designed, is then

$$\left[1 - \left(\frac{3.52-3.40}{3.46}\right)\right] \times 100 = 96 \text{ percent}$$

96 percent with respect to costs. This represents an excellent effectiveness with respect to system design.

Effectiveness of manpower utilization is fairly good for the site. Nonproductive or waiting time is ineffective utilization of personnel. From Table 18, the manpower utilization is:

	Productive Time (Man-min.)	Nonproductive Time (Man-min.)	Total Time (Man-min)	Percent Time Utilization Effectiveness
SFA, SFD, MFLR units (ea. pickup)	102	14	116	88%
MFM/HR units (ea. pickup)	52	8	60	87%
All units (per week)	360	52	412	87%

The refuse collection system results in 87 percent effective utilization of personnel.

Resident Acceptance - Site management has not received any complaints from residents. The containers and surrounding areas are clean. Residents appear to fully accept and use the system. A separate report will summarize the results of a resident survey at the Macon site to determine the level of user acceptance of the refuse management system (see Ref.2). In general, the survey found that the residents accept the system but about one third believe the system to be inadequate with respect to environmental concerns; odors, insects, weather and pets were cited as problems. The survey also found that residents believed that there is a requirement to place refuse in plastic bags; however, there is no such requirement. The believed requirement may have resulted from requirements at community developments where residents previously lived since most residents had lived at the site for a very short time, less than a year, at the time of the survey.

Site Appearance -

The containers and enclosures are highly visible in the parking lots. The areas surrounding the containers are clean and free from litter. The compactor and containers in the MFM/HR building are closed off from view by doors; however, the doors are usually left open. The compactor room was littered with refuse on each day observed necessitating cleanup every morning by site personnel. If the doors were closed, residents could not toss refuse into the room and insects and pets could not gain access to the refuse to dig through and scatter the refuse from the containers.

Environmental Considerations -

The environmental considerations include odors, sanitation, and noise problems. The spraying of the containers effectively minimizes odors and insects. In hot weather, some odors occur which are noticeable when within 10 feet of the containers. A particular problem occurred while container collection was being observed. A watery fluid flowed from the truck each time the contents of a container were compacted. The fluid fell onto the parking areas around the site. The fluid constituency is unknown as well as any effect the fluid may have on site sanitation. No particular odor emanated from the fluid. The packer truck is noisy when emptying containers and packing refuse; also, the noise is very obvious to residents because their homes are located very close to the parking areas where the containers are serviced.

Results

The results are presented as the advantages and disadvantages of the Macon refuse collection system in economics, effectiveness, efficiency, and environmental aspects.

Economic Advantages -

Reasonable capital expenditures are required by the site for the system as installed at the Macon site. A proper installation for the compactor could have minimized site labor requirements. The use of centrally located containers around the site minimizes the labor requirements for refuse collection. Only one man and a packer truck are required to collect and dispose refuse. Also, the single highest cost item is the private service contract. By concentrating costs in this manner, bookkeeping and accounting are made easy at the site.

Economic Disadvantages -

Actual installation problems encountered at the interface of the refuse chute to the compactor results in chute blockages and the expenditure of site labor to clean the chute. The utilization of site labor for this purposes increases system operating costs. The cost of the private contractor service results in high operating and maintenance costs to the site. The service is 55 percent of total annual costs. If fewer pickups could be utilized without causing detrimental environmental effects, reduced costs could be achieved; however, the problem should be studied carefully before reducing the number of pickups per week.

Effectiveness, Advantages -

Refuse is effectively collected and removed. The cost effectiveness is high, estimated at 96 percent. Handling of refuse is minimized in the use of centrally located containers. A properly operating compactor installation could also minimize refuse handling and the use of labor.

Effectiveness, Disadvantages -

The parking areas are not large enough for a packer truck to easily maneuver to empty containers. Walking time and some nonproductive labor could be reduced. It will not reduce overall costs much, but consideration for future sites should include planning to reduce labor requirements. The containers inside of pens must be rolled out and positioned in front of the packer truck. After emptying, the container must be rolled back. Future sites should contain provisions for allowing direct access to the container by the truck. The improper compactor installation causes chute blockages and requires site labor to make the system properly perform.

Efficiency, Advantages -

The collection system as installed results in 87 percent utilization of labor for productive refuse collection activities. A minimal amount of refuse handling is required.

Efficiency, Disadvantages -

Thirteen percent of the labor requirements are for nonproductive activities. The site load of about 65 cu yd per week for the SFA, SFD, and MFLR units indicates that the 23 containers do not need servicing twice a week. The containers are 4 cu yd which provides 92 cu yd total capacity in the containers. Likewise, proper compactor utilization could reduce servicing to twice per week for the compactor containers. Collection activities and costs of collection might be minimized if private contract services were reduced to once a week pickup for the SFA, SFD, and MFLR units. The number of collections per week appears high for the site.

Environmental Considerations -

Advantages - The site is clean and free from odors, insects, and vermin. The aesthetics are fairly good even though containers are fairly visible. Handling of refuse is minimized.

Environmental Considerations -

Disadvantages - The truck is noisy and liquids tend to be squeezed out of the refuse and leak to the parking areas. Since all units at the site have garbage disposals, it might be assumed that the liquid was contained in refuse collected by the truck prior to servicing the site or the liquid is water which has collected in containers from rain. Packer trucks should have some provision to prevent liquids from being squeezed out of the truck onto the parking lot or grounds of a residential area. The MFM/HR refuse room becomes messy and littered with refuse due to an unlocked and usually open door to the room, the inconsiderate throwing of paper bags full of refuse into the room, and access allowed to dogs and cats. Refuse rooms, where residents need not open doors, should be closed and possibly locked at all times when not being attended.

MEMPHIS, TENNESSEE

The Memphis site was visited on October 22, 23, and 24, 1973. The refuse management system consists of fourteen 3-cu yd containers in concrete pens distributed among the SFA and MFLR residences and serviced three times per week, two 3-cu yd containers in one MFHR building each chute-fed and each serviced six times per week, and two 2-cu yd containers for attachment to a compactor in the other MFHR building and serviced twice each week. All containers are serviced through contracts with private companies. The typical container and pen, compactor, and collection vehicle are shown in Figures 17 through 20. The site arrangement is shown in Figure 21. Site demographic and other data are given in Table 19.

Refuse System Description

SFA and MFLR residents of the Memphis site take their refuse to centrally located 3-cu yd containes. MFHR residents deposit their refuse in a refuse chute. One MFHR building has a trash chute at each end of the building and a 3-cu yd container at the base of each chute. The other MFHR building has a chute-fed compactor with two 2-cu yd containers. Refuse is collected

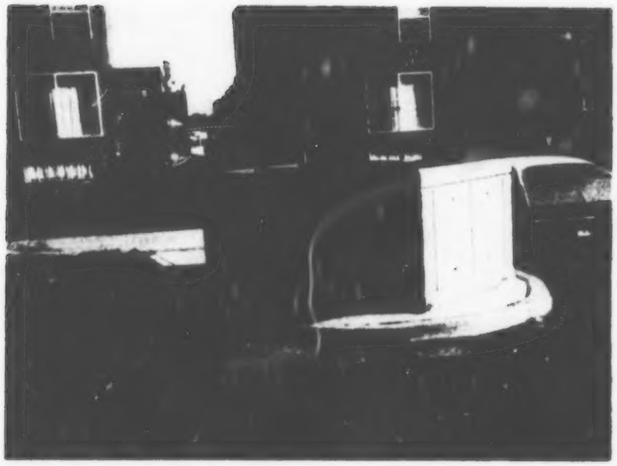

FIGURE 17. Typical 3-cu yd container and concrete pen installation at the Memphis site. Note that the container is not set inside the pen because of lack of clearance room.

FIGURE 18. Compactor with container attached in one of the MFHR buildings on the Memphis site.

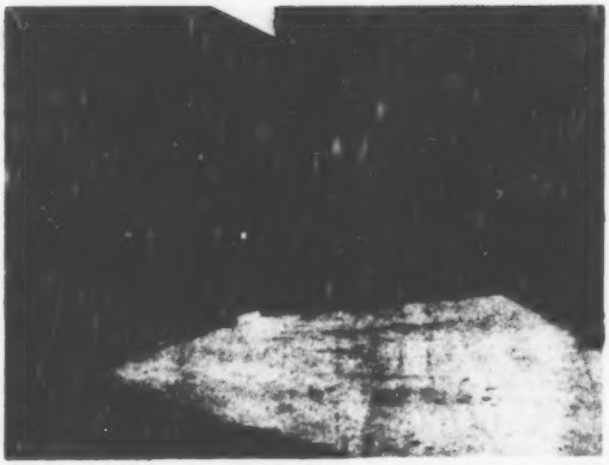

FIGURE 19. Ramp to compactor room in the MFHR building on the Memphis site. The compactor container in the foreground is fully compacted. The other containers are temporarily provided for boxes from residents moving into the building.

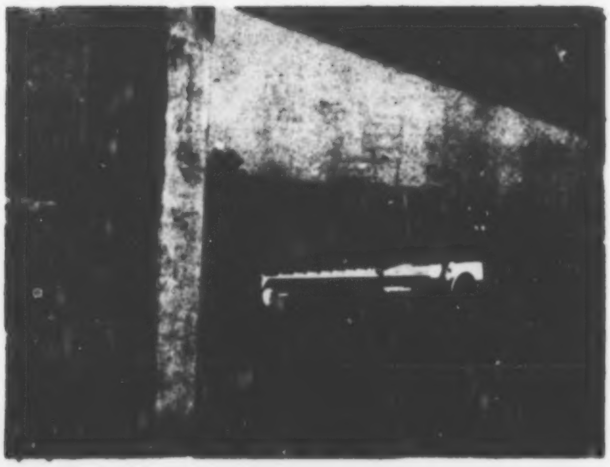

FIGURE 20. Typical 31-cu yd packer truck as used for collecting refuse from containers at the Memphis site.

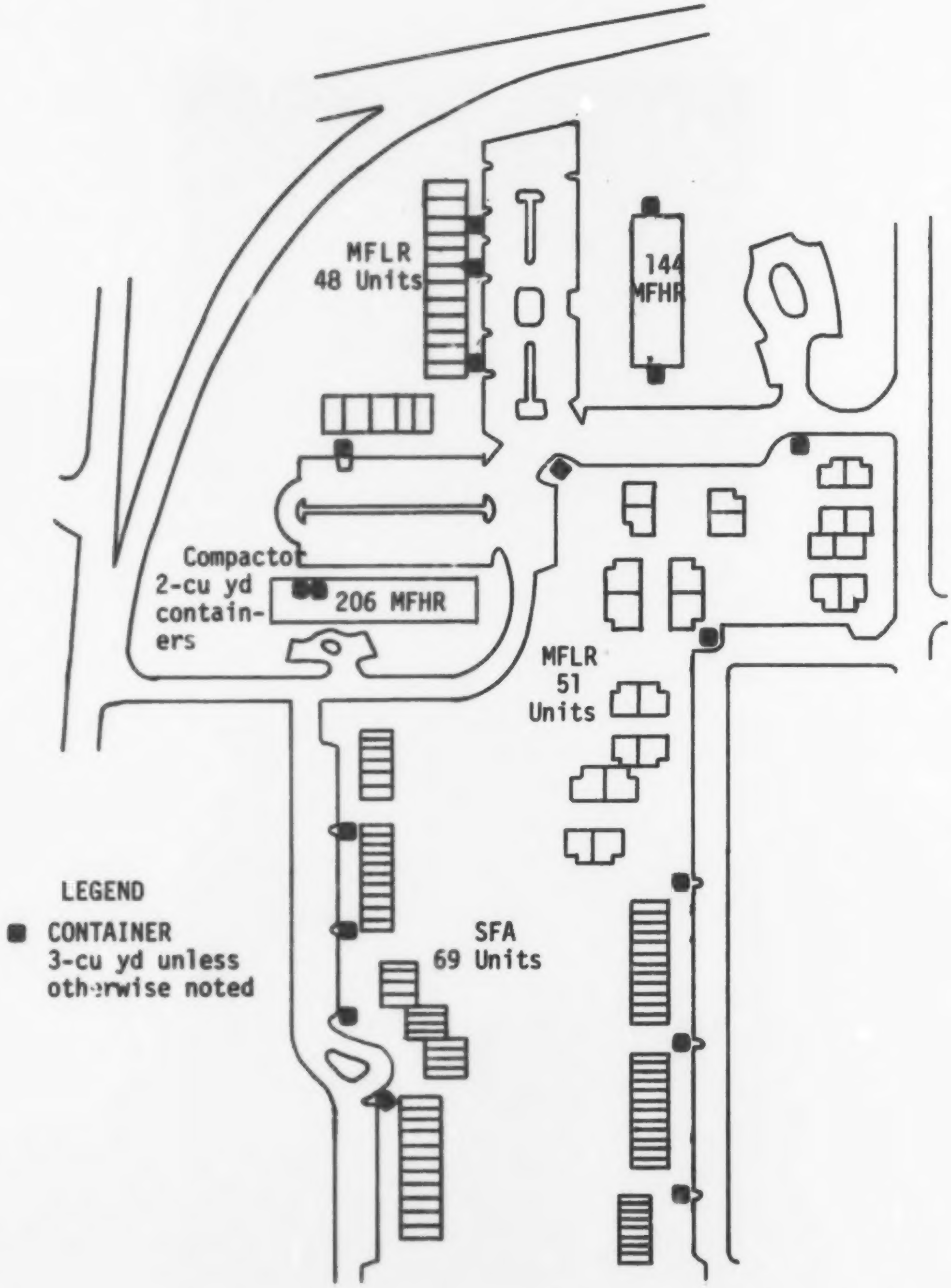
MFLR
48 Units
144 MFHR
Compactor
2-cu yd containers
206 MFHR
MFLR
51
Units
SFA
69 Units
LEGEND
■ CONTAINER
3-cu yd unless otherwise noted

FIGURE 21. Memphis Operation Breakthrough site arrangement showing locations of containers and the compactor

in packer trucks by private contractors as described above and in Table 19. The packer trucks require only a driver for operation. The driver and truck service all containers for the SFA and MFLR units without external assistance. The compactor containers in one MFHR building are rolled out to the parking area by site personnel for emptying by the truck. The truck driver plus site personnel roll the containers in the other MFHR building to the parking area for emptying by the truck. Container pens, refuse container rooms, and the compactor room are cleaned by site personnel.

Table 19. DEMOGRAPHIC AND REFUSE SYSTEM DESCRIPTIVE DATA FOR THE MEMPHIS OPERATION BREAKTHROUGH SITE

Number and Type of Dwelling Units and Occupancy:

Type	No.	Vacancies	Residents
SFA	69 units	0 units	215 people
MFLR	99	0	197
MFHR	350	49	396
Totals	518 units	49 units	808 people

Number Occupied:	469 units
Number Residents:	808 people
Site Area:	15.9 acres

Distribution of Units to Each Refuse Service Point:

Number and Type	Service Description
69 SFA, 48 MFLR	10 containers in pens (3-cu yd ea) three pickups per week
51 MFLR	4 containers in pens (3-cu yd ea) three pickups per week
144 MFHR	2 chutes, 2 containers (3-cu yd ea) six pickups per week
206 MFHR	1 chute, 1 compactor, 2 containers (2-cu yd ea) two pickups per week

Average Number of Units per Service:	30.5
Average Number of People per Service:	47.5

Based on observation of refuse system activities for three days at the Memphis site, approximately 175 cu yd of loose refuse are collected each week, or approximately 9100 cu yd are collected per year. The refuse volume was estimated from the collected amounts of loose refuse in containers and from the compacted refuse concentrated at a ratio of ten parts loose to one part compacted. The volume of refuse collected on each site visit does not fill the packer truck. The truck services other urban areas before and after servicing the Memphis site.

Economic Analysis

The economic data are tabulated in Table 20 in general form. The private service contractor represents $12,414 or 55 percent of the estimated annual costs of refuse collection and disposal. Costs of various elements of the private contractor services are estimated from discussions with each of the two contractors. The apportioned costs for contractor services are shown in Table 21 and are based upon time spent on the site by each contractor vehicle and driver. The expense to the site associated with each element of refuse collection and disposal is shown in Table 22. Labor and landfill fees account for 52 percent of the expense to the site. The city inspection fee is 16 percent of the expenses. The costs are $25.35 per capita per year as compared to the adjusted national survey average of $12.08 per capita per year.

Technical Analysis

The collection and disposal of refuse at the Memphis Operation Breakthrough site was observed for three days. Based on estimated volumes of observed refuse, the loose refuse collected is 175 cu yd per week or 9100 cu yd per year for the 469 occupied units and 808 people. The technical data for refuse collection and disposal are summarized in Table 23 including distance traveled, number of stops, dwelling units serviced, crew size, refuse collected, estimated volume, elapsed time, and labor time expenditures. The data in Table 23 were observed for the 90 percent occupied site. The nonproductive time is considered as all waiting and packing time. Riding, walking, and handling refuse are productive activities.

Equipment Performance -

Suitability - The two containers in the #2 high-rise building (144 units) must be emptied six days a week which appears to be a high pickup rate. Two compactors might be more suitable. Estimated annual costs for two compactors and twice weekly pickup service for the #2 high-rise as opposed to the six-day service are shown below:

	Current Design with Containers	New Design with 2 Compactors
Capital Costs:		
Two Chutes	$ 550	$ 550
2 Compactors & Containers	60	1,836
	$ 610	$2,386
Recurring Costs:	$1,011	$1,011

Table 20. COST OF REFUSE COLLECTION AND DISPOSAL AT THE MEMPHIS OPERATION BREAKTHROUGH SITE

	Initial Costs	Multiplier[a]	Oct. 1975 Costs	Carrying Charge[b]	Annual Costs	Cost Per DU Per Yr. (518)[c]	Cost Per Cap. Per Yr (892 people)[c]	Cost Per Cu Yd (10,100 cu yd/yr)[c]
Capital Costs								
Compactor, 2 containers[d]	$ 5,374	1.1707	$ 6,291	0.146	$ 918			
Chute in 1 MFHR building[d]	3,000	1.1707	3,512	0.079	277			
Two Chutes in 2nd MFHR building[e]	5,948	1.1707	6,963	0.079	550			
Two Containers in 2nd MFHR building[e]	350	1.1707	410	0.146	60			
Container pens, concrete[f]	11,681	1.1707	13,675	0.079	1,080			
					$ 2,885	$ 5.57	$ 3.23	$ 0.29
Recurring Costs								
City inspection fees[g]	$ 3,108	1.1902	$ 3,699	NA	$ 3,699	$ 7.14	$ 4.15	$ 0.37
Operating and Maintenance Costs								
Private contract services for compactor containers[h]	$ 1,236	1.1707	$ 1,447	NA	$ 1,447			
Private contract for 16 containers[i]	9,368	1.1707	$10,967	NA	10,967			
On-site labor[j]	1,752	1.1902	2,085	NA	2,085			
On-site labor[k]	1,286	1.1902	1,531	NA	1,531			
					$16,030	$30.94	$17.97	$ 1.59
Total Annual Costs					$22,614 per year	$43.65 per DU per year	$25.35 per capita per year	$ 2.25 per cu yd

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a - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.
b - The carrying charge is interest plus sinking fund factor. See Section I for explanation.
c - Occupancy was 469 dwelling units. The number of people and volume of estimated refuse were multiplied by 518/469 to adjust to total site occupancy.
d - Compactor, chute, containers, and installation for $8,374. Chute life is 40 years. Container and compactor life is 10 years. October 1973 data.
e - Two chutes totaling $5,948 for chutes and installation; life is 40 years. Two containers at $175 each with 10-year life. October 1973 data.
f - $11,681 for container pens. Life is 40 years. October 1973 data.
g - City charge $.50 per dwelling unit per month as an inspection fee. October 1973 data.
h - $103 per month contract for two containers picked up twice each week. October 1973 data.
i - $720.62 every four weeks for 14 containers serviced three times a week and two containers serviced six times a week. October 1973 data.
j - 422 man-hours per year at $3.46 per hour plus 20% fringe benefits (site labor). October 1973 data.
k - 264 man-hours per year at $10.40 per hour including fringe benefits (city housing authority labor). October 1973 data.

Table 21. APPORTIONED COSTS TO THE MEMPHIS SITE FOR SEGMENTS OF COSTS OF THE PRIVATE SERVICE CONTRACTORS

(October 1975 Basis)

	Contractor No. 1			Contractor No. 2			Total Annual Costs to Site[h]
	Annual Cost[a]	Apportionment Factor	Site Annual Costs[h]	Annual Cost[b]	Apportionment Factor	Site Annual Costs[h]	
Capital Costs							
Truck (5-yr life)[c]	$102	13%	$ 188	$ 981	19%	$ 2,084	$ 2,272
Containers (10-yr life)[d]	0	0	0	479	9	987	987
	$102	13%	$ 188	$1,460	28%	$ 3,071	$ 3,259
Recurring Costs							
Licenses, insurance	$ 10	1%	$ 14	$ 95	2%	$ 219	$ 233
Operating and Maintenance Costs							
Labor w/20% fringe benefit[e]	$128	17%	$ 246	$1,245	24%	$ 2,632	$ 2,878
Supervisory costs[f]	49	6	87	467	9	987	1,074
Fuel, lubricants, maintenance	39	6	87	364	7	768	855
Landfill fees[g]	438	57	825	1,623	30	3,290	4,115
	$654	86%	$1,245	$3,699	70%	$ 7,677	$ 8,922
Total Costs	$766	100%		$5,254	100%		
Contractor Annual Site Costs			$1,447			$10,967	$12,414

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a - 26 hours per year on-site out of 2496 hours per year that truck is operated (carrying charge included). Costs are estimated and exclude profit.
b - 249 hours per year on-site out of 2496 hours per year that truck is operated.
c - $34,000 vehicle
d - $175 each for new container (16 containers).
e - $3.50 per hour plus 20% fringe benefits.
f - $8.75 per hour plus 20% fringe benefits, 15% of labor time.
g - $0.45 per cu yd. Charge $0.90 per cu yd for compacted refuse.
h - Estimated site costs include private contractor profit.

Table 22. COMBINED SEGMENTS OF ANNUAL EXPENSES FOR REFUSE COLLECTION AND DISPOSAL AT THE MEMPHIS SITE

Cost Segments	Private	Site	Segment Total	Percent of Annual Total
Capital Costs				
Compactor, containers, chute, MFHR#1		$1,195	$ 1,195	5%
Chute, 2 containers, MFHR#2		610	610	3
Container pens, concrete		1,080	1,080	5
Trucks, packer	$ 2,272		2,272	10
Containers	987		987	4
	$ 3,259	$2,885	$ 6,144	27%
Recurring Costs				
City inspection fees		$3,699	$ 3,699	16%
Licenses, insurance	$ 233		233	1
	$ 233	$3,699	$ 3,932	17%
Operating and Maintenance Costs				
Labor	$ 3,952	$3,616	$ 7,568	34%
Operating, maintenance	855		855	4
Landfill fees	4,115		4,115	18
	$ 8,922	$3,616	$12,538	56%
Totals	$12,414	$10,200	$22,614	100%

Annual Total Costs $22,614 per year

Table 23. OBSERVED REFUSE COLLECTION ACTIVITIES AT THE MEMPHIS SITE FOR ONE PICKUP AND ONE YEAR WITH ANALYTICAL RESULTS

Service	Distance Traveled	No. of Stops	No. of Units	Crew Size	Items Collected	Estimated Loose Volume	Time Elements				Total Man-Time
							Elapsed	Riding	Walking/Handling	Waiting/Packing	
(1) Site cleanup, site personnel; once per day, 7 days per week:											
			469	1	litter	-	3600 seconds	0	3600 man-sec.	0	3600 man-sec.
(2) Private, 2 pickups per week, #1 MFHR:											
	0.2 mi.	1	157	1	2 containers (compacted)	40 cu yd	890 seconds	45 man-sec.	745 man-sec.	100 .man-sec.	890 man-sec.
(3) Site support to private servicing for #1 MFHR, line (2) above, 2 times per week:											
	-	-	-	2	-	-	1240 seconds	0	2480 man-sec.	0	2480 man-sec.
(4) Private, 3 pickups per week, SFA, MFLR, #2 MFHR:											
	1.0 mi.	16	312	1	16 containers	26 cu yd	4155 seconds	1075 man-sec.	1895 man-sec.	1185 man-sec.	4155 man-sec.
(5) Private, 3 pickups per week, #2 MFHR, in addition to (4) above:											
	0.2 mi.	2	144	1	2 containers	6 cu yd	1585 seconds	300 man-sec.	564 man-sec.	721 man-sec.	1585 man-sec.
(6) Site support to private servicing of #2 MFHR in (4) and (5) above, 6 days per week:											
	-	-	-	1	-	-	1270 seconds	0	1030 man-sec.	240 man-sec.	1270 man-sec.
Total Per Year	208 mi. per year	2912 stops/yr	469	1	3016 containers/year	9100 cu yd per year	639 hr/yr (collection) 510 hr/yr (support)	61 man-hr/yr	289 man-hr/yr (excludes cleanup) 364 man-hr/yr (cleanup)	106 man-hr/yr	456 man-hr/yr 364 man-hr/yr
								61	653	106	820 man-hr/yr

Analytical Results

Average distance per stop: 0.1 miles per stop
Average labor per stop (excluding cleanup): 9.4 man-minutes per stop
Average dwelling unit density per stop: 26.1 dwelling units per stop (18 stops)
Average labor per cu yd (excludes cleanup): 3.0 man-minutes per cu yd
    Riding: 0.4 man-minutes per cu yd
    Walking/Handling: 1.9 man-minutes per cu yd
    Waiting/Packing: 0.7 man-minutes per cu yd

	Current Design with Containers	New Design with 2 Compactors
Operating and Maintenance Costs:		
On-site labor (estimate)	$ 544	$ 354
Private contractor service (estimate)	6,057	2,894
	$6,601	$3,248
Total Annual Costs	$8,222	$6,645

An estimated annual savings of $1,577 could be achieved if two compactors were installed in place of the containers in the #2 high-rise.

The containers in both high-rise buildings must be rolled down inclined ramps about 60 to 80 feet to the parking lot where they can then be emptied into the truck. The containers have caster wheels. The container full of compacted refuse from #1 high-rise (200 units) is difficult to control on the ramp because of its weight. The containers in the #2 high-rise are also difficult to control. The Memphis Housing Authority is planning to install a winch for handling the compactor containers. As installed, the requirement to move full containers down the ramp is unsuit able because of hazard to personnel moving the containers.

The concrete pens are not properly sized for the containers which causes difficulty to the truck. The containers are not easily aligned with the truck and cannot be easily replaced in the pens after dumping. Pipes were installed in the pens to protect the concrete from being hit; however, the pipes obstruct the containers and do not allow the containers to be set flush into the pens. Containers located under the deck must be picked up and moved to an opening so that they can be emptied overhead without hitting the deck.

Effectiveness - Refuse is effectively collected and disposed by the system. The compactor effectively concentrates refuse and permits reduced pickup visits. The system is operating very nearly as it was designed to be operated; consequently, the cost effectiveness is high, very close to 100 percent. Moving the containers from the high-rise buildings down a ramp is not an easy task for two men. Three pickups per week do not appear necessary for the SFA and MFLR containers. Only two of the 14 containers were full, two were two-thirds full, and the other 10 were less than half full on the day observed. The effectiveness could be improved through use of compactors in the #2 high-rise building.

Residence Acceptance - Site management has received no complaints. Some refuse is spilled between containers and pens causing litter and odors. A separate document reports the results of a resident survey at the site. The results of the survey in general found that a shortage of containers was indicated by respondents; this finding was not indicated in the visits for analyzing economic and technical aspects of the system.

Site Appearance -

The containers are located inside concrete pens in parking areas and inside refuse rooms and do not affect site appearance. Site neatness could be improved if the containers could be fitted flush inside the pens. The protective pipes would have to be removed. Some accumulation of refuse occurs between the container and the pen because refuse can fall into the gap and access is not easily attained to clean it out except when the container is removed. About once a month, site personnel go with the collection truck to clean out the pens.

Environmental Considerations -

There are no apparent sanitation problems. The collection truck makes some noise, but residents are not bothered and do not complain. Some odors are created in hot weather in the containers for the SFA dwelling units. The SFA containers are located in direct sunlight and on warm days some odor is noticeable. All other containers are either inside refuse rooms or are under the deck area which is between the MFHR and MFLR buildings.

Results

The results are presented as the advantages and disadvantages of the Memphis refuse collection system in economics, effectiveness, efficiency, and environmental aspects.

Economic Advantages -

Capital expenditures are low.

Economic Disadvantages -

The refuse collection and disposal expense is high at $25.35 per capita per year. The operating and maintenance expenditures are primarily for the private service contracts which account for $13.92 per capita per year or 55 percent of the total cost for refuse collection and disposal. If compactors were used in the #2 high-rise, it is estimated that the overall costs could be reduced by $1.77 per capita per year which represents a 7 percent reduction in costs. A city inspection fee of $0.50 ($0.59, October 1975 costs basis) per dwelling unit per month is levied against the site as a recurring charge. There is no reduction in landfill fees for compacted refuse. Future compactor installations should consider the basis of hauling and dumping charges during the planning stages. If reduced volume does not save money, the only reason to install the equipment is to reduce the number of pickups.

Effectiveness, Advantages -

Refuse is effectively removed. Minimal refuse handling is achieved. Containers appear well located for use by residents.

Effectiveness, Disadvantages -

The use of containers under a deck where overhead loading is difficult is not good. Three pickups per week appears excessive for the SFA and MFLR units. The refuse from the 144 unit MFHR fills two containers which are emptied six times a week. A compactor arrangement could reduce the required pickups per week and reduce overall costs to the site. Installation of compactors should reduce the number of pickups to a maximum of three pickups per week. This would not reduce dumping charges, but it should reduce pickup fees and reduce the labor expended in removing backed-up refuse in the chute. The containers and pens are not properly sized for a good fit. The concrete pens do serve to blend the containers into the site; however, future sites should more closely match pen size to container size so that the container will fit into the pen. Pen orientation should be considered for ease of emptying by the truck. Also, some pens could be blocked by parked automobiles.

Efficiency, Advantages -

Personnel requirements are minimal, but the efficiency of labor utilization could be improved.

Efficiency, Disadvantages -

Personnel from the site are used to move containers from the 144-unit MFHR building and accrue 21 man-hours per year of waiting (nonproductive) time. The truck drivers accrue 75 man-hours per year of waiting time while servicing the site. Eighty-seven man-hours of the total of 96 nonproductive man-hours used per year are associated with moving and emptying the two chute-fed containers in the 144-unit MFHR structure. The other nine hours are associated with waiting for residents to move automobiles in the parking areas next to the SFA units. The collection labor utilization efficiency is 77 percent.

Environmental Considerations -

Advantages - Site aesthetics are good and the containers are unobtrusive. There are very little odor and noise problems. There are no sanitation problems.

Disadvantages - A safety problem exists for personnel moving the containers out of the two MFHR buildings. The containers tend to overpower the two men when moving containers downhill on ramps to the parking areas where the truck can empty them. The hazardous situation exists because the containers must be manually pushed down inclined ramps to the truck. This requires dexterity and a fair amount of strength to prevent the heavily laden containers from running wildly down the inclines possibly crashing into automobiles in the parking lots or injuring personnel. The manual movement of the containers is consumptive of time and labor.

ST. LOUIS, MISSOURI

The St. Louis site was visited on July 29, 30, and 31, 1974. The site studied consisted of three sections: La Clede Town East, La Clede Town West and La Clede Town. The east and west sections are housing built as part of the Operation Breakthrough program. La Clede Town is the middle section and was constructed before the Operation Breakthrough sections. The La Clede Town section is comprised of SFA housing which employ sidewalk (similar to backyard) collection of refuse by site personnel from site provided containers. The Operation Breakthrough housing, La Clede Town East and West, consists of MFLR, MFMR, and MFHR buildings. The MFLR and MFMR units are equipped with household compactors. The MFHR units (two buildings) have chute-fed compactors. The refuse system is described below and depicted in Figures 22 through 29. The site arrangement is shown in Figure 30, and site demographic and other data are given in Table 24.

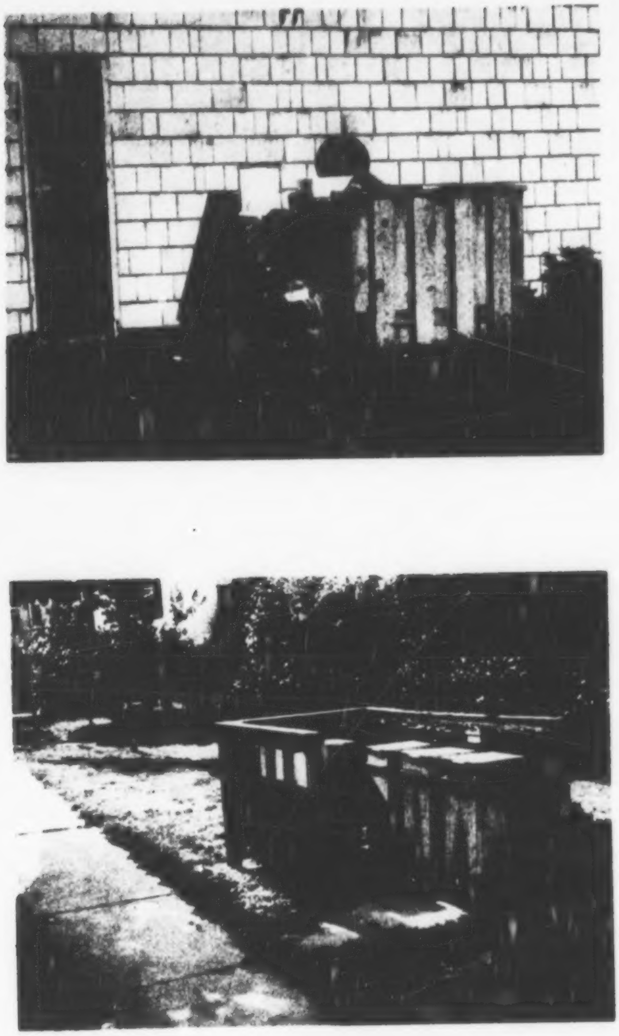

FIGURE 22. Thirty-five gallon containers and enclosures as used for refuse in La Clede Town, St. Louis, MO. There are 587 containers and 127 redwood enclosures around the site. Plastic bag liners are replaced each day in each container.

FIGURE 23. Tractor and trailer used by four men to collect refuse from containers in La Clede Town. Refuse is collected six days per week.

FIGURE 24. West and east views of pen where La Clede Town refuse is stored for pickup by municipal service.

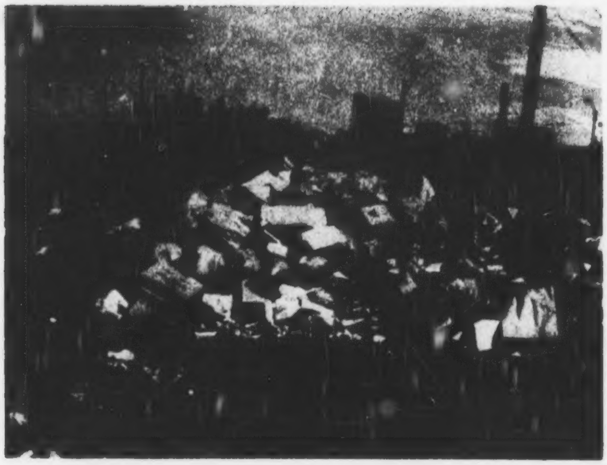

FIGURE 25. Closeup photograph of La Clede Town refuse pen which shows bags of refuse intact and broken open, yard wastes, and appliances.

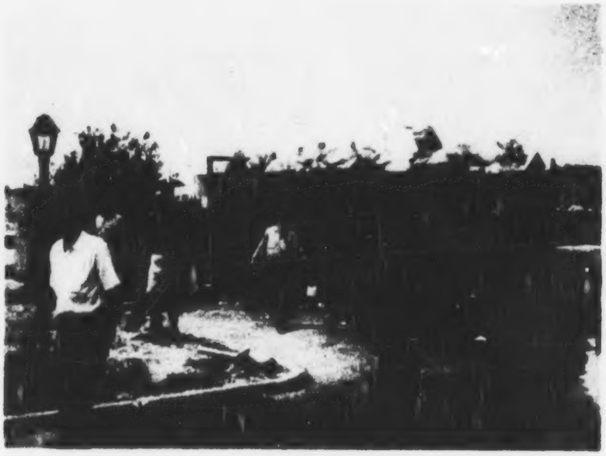

FIGURE 26. Roll-off 30-cu yd container used at La Clede Town refuse storage pen to supplement municipal removal services.

FIGURE 27. Typical chute-fed compactor installation in the MFHR buildings. Two are installed, one in the MFHR in La Clede Town East and the other in the MFHR in La Clede Town West. A private contractor services the containers.

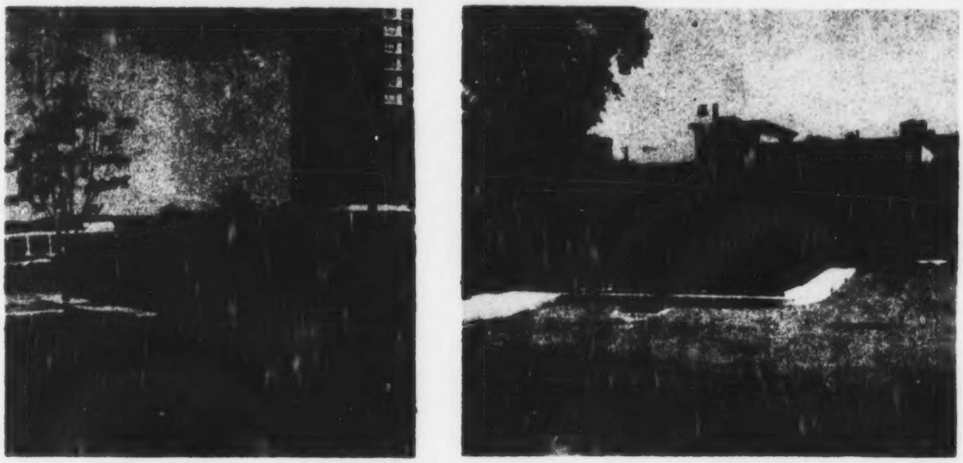

FIGURE 29. Refuse storage pens for refuse from the MFLR and MFMR buildings of La Clede Town East and West sections. Refuse is picked up by site personnel and stored in the pens until picked up by municipal service.

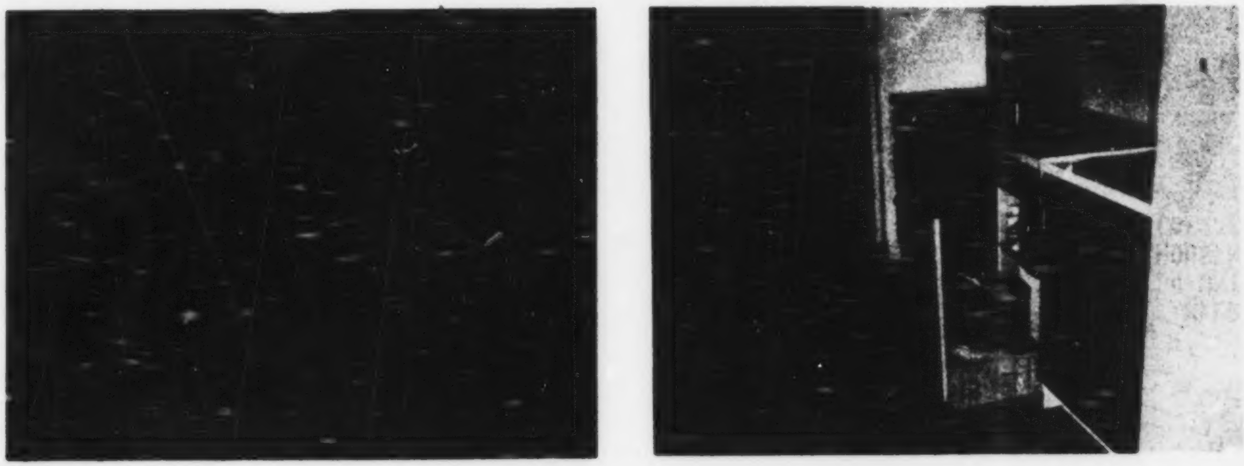

FIGURE 28. Typical of the household compactor installations in the MFLR and MFMR buildings in La Clede Town East and West. When full, bags are placed in containers, two per building, for pickup by site personnel.

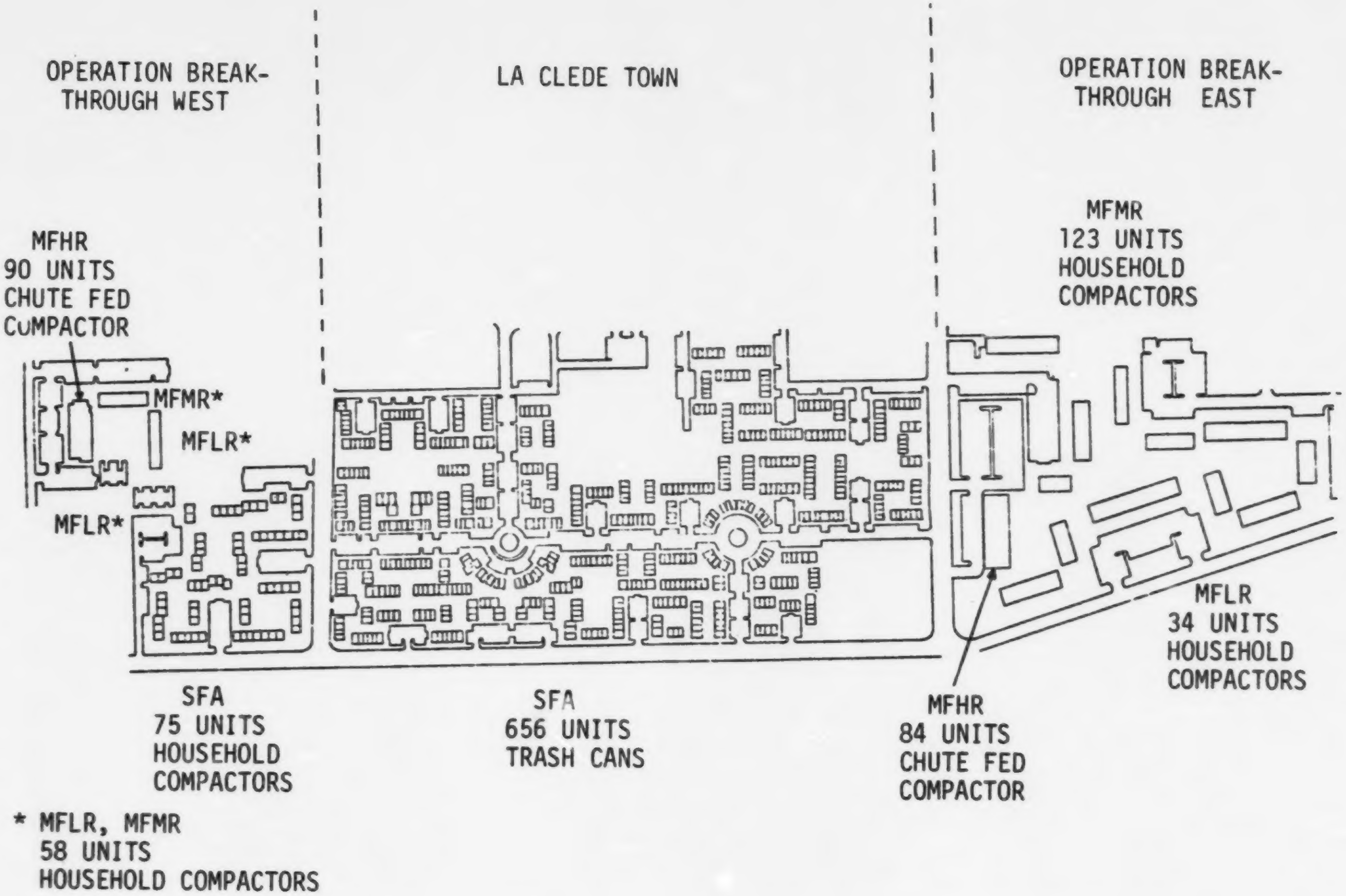
OPERATION BREAK-
THROUGH WEST
LA CLEDE TOWN
OPERATION BREAK-
THROUGH EAST
MFHR
90 UNITS
CHUTE FED
COMPACTOR
MFMR*
MFLR*
MFLR*
MFMR
123 UNITS
HOUSEHOLD
COMPACTORS
MFLR
34 UNITS
HOUSEHOLD
COMPACTORS
SFA
75 UNITS
HOUSEHOLD
COMPACTORS
SFA
656 UNITS
TRASH CANS
MFHR
84 UNITS
CHUTE FED
COMPACTOR
* MFLR, MFMR
58 UNITS
HOUSEHOLD COMPACTORS

FIGURE 30. St. Louis site arrangement.

Table 24. DEMOGRAPHIC AND SOLID WASTE SYSTEM DESCRIPTIVE DATA FOR THE ST. LOUIS OPERATION BREAKTHROUGH SITE

Number and type of dwelling units and occupancy:

Type	No.	Vacancies	Residents	Type of Refuse Service
La Clede Town West (part of Operation Breakthrough housing):				
MFLR	34	3	69	Household Compactors
MFMR	24	1	51	Household Compactors
SFA	75	4	158	Household Compactors
MFHR	90	4	191	Chute-fed Compactor
La Clede Town East (past of Operation Breakthrough housing):				
MFLR	34	1	73	Household Compactors
MFMR	123	3	268	Household Compactors
MFHR	84	1	185	Chute-fed Compactor
La Clede Town:				
SFA	656	5	1700 (estimated)	Backyard Pickup

Number occupied	1098 units
Number residents	2695 people
Site area	24.5 acres

Distribution of units by type of service:

Number and Type	Description
656 SFA	Backyard pickup from 35-gal. containers
75 SFA	Household compactors with backyard pickup
68 MFLR	Household compactors with two containers per building
147 MFMR	Household compactors with two containers per building
174 MFHR	Chute-fed compactors with private service

Refuse from SFA, MFLR, and MFMR buildings is collected six days per week and stored in pens for municipal pickup and disposal twice a week. Refuse from MFHR buildings is collected twice a week by a private contractor.

Refuse System Description

La Clede Town East and West -

Residents of La Clede Town East and West who live in SFA, MFLR, and MFMR units dispose of refuse using household compactors. When the compactor chamber is full, the bag is removed and carried to a collection point. SFA residents set their bags curbside for daily pickup by site personnel. The plastic compactor bags are furnished by site management. MFLR and MFMR residents place their bags in containers, two to each building, located next to stairs at ground level; site personnel empty the containers on a daily basis. The bags are stored in pens while awaiting collection by municipal service. MFHR residents place their refuse in vertical chutes which lead to compactors, one at the base of a chute in each building. The compactor containers are rolled to parking areas for servicing twice a week by a private contractor.

La Clede Town -

La Clede Town residents place their refuse in 35-gallon containers. Five hundred eighty-seven containers are located along sidewalks throughout La Clede Town. The site personnel empty the containers and reline with plastic bags six days a week. The refuse is collected by a four-man crew using a tractor and trailer. The bags of refuse are stored in a pen while awaiting pickup and disposal by the municipal service. When the pen becomes overloaded, a 30-cu yd container is brought in, filled, and disposed of by a private contractor.

Economics Analysis

The economic data are tabulated in Tables 25, 26, and 27 in general form for the sections of the site and for the whole site. The cost of various segments of the city and private collection and disposal services were not available. Based on observations at the site of the equipment and apportioning to labor used, the costs are estimated and given in Table 28 for elements of capital, recurring, operation and maintenance costs. Labor, disposal fees, compactors including containers, and plastic bags account for 87 percent of the total annual costs for refuse collection and disposal. Labor and disposal fees together account for 63 percent of the annual costs.

The costs are $46.00 per capita per year as compared to $12.08 per capita per year from the adjusted national survey results.

Table 25. COST OF REFUSE COLLECTION AND DISPOSAL AT LA CLEDE TOWN EAST AND WEST, THE OPERATION BREAKTHROUGH PORTIONS OF THE ST. LOUIS SITE

	Initial Costs	Multiplier[a]	Oct. 1975 Costs	Carrying Charge[b]	Annual Costs	Cost Per DU Per Yr (464)[c]	Cost Per Cap. Per Yr (995)[c]	Cost Per Cu Yd (2800 cu yd per yr)[c]
Capital Costs:								
Household Compactors[d]	$58,004	1.0914	$63,306	0.247	$15,637			
Central Compactors and Containers[e]	24,925	1.0914	27,203	0.146	3,972			
Storage pens[f]								
Slabs	1,970	1.0914	2,150	0.079	170			
Fence	907	1.0914	930	0.179	177			
Tractor and Trailer[g]	386	1.0914	421	0.299	126			
					$20,082	$ 43.28	$20.18	$ 7.17
Recurring Costs:								
City (Budget)[h]	$11,600	1.1228	$13,024	NA	$13,024	$ 28.07	$13.09	$ 4.65
Operation and Maintenance Costs:								
Labor[i]	$ 3,120	1.1228	$ 3,503	NA	$ 3,503			
Private contract service[j]	2,080	1.0914	2,270	NA	2,270			
Tractor and trailer fuel, lubricants, maintenance	5	1.0914	5	NA	5			
Household compactor maintenance	5,400	1.1228	6,063	NA	6,063			
Central compactor maintenance	1,200	1.1228	1,347	NA	1,347			
Compactor bags	6,739	1.0914	7,355	NA	7,355			
					$20,543	$ 44.27	$20.65	$ 7.34
Total Annual Costs:					$53,649 per year	$115.62 per DU per year	$53.92 per capita per year	$19.16 per cu yd

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a - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.
b - The carrying charge is interest plus sinking fund factor. See Section I for explanation.
c - Occupancy was 447 dwelling units. The number of residents and the observed refuse collected are multiplied by 464/447 to adjust to total site occupancy.
d - Five-year life, 290 compactors, initial cost of $58,004 (July 1974).
e - Ten-year life, 2 compactors, 4 containers, initial cost of $24,925 (July 1974).
f - Concrete slabs at $1970, forty-year life. Wood fence at $907, 7.5-year life (July 1974).
g - $1170 initial costs, four-year life, used 33 percent of time for refuse collection (July 1974).
h - City budgets $25 per dwelling unit per year from general revenue funds for refuse collection (July 1974).
i - Two men, 2 days per week, 4 hours per day, at $3.75 per hour including 20 fringe benefits (July 1974).
j - $40 per week for servicing 4 containers per week (July 1974).

Table 26. COSTS OF REFUSE COLLECTION AND DISPOSAL AT THE LA CLEDE TOWN PORTION OF THE ST. LOUIS SITE

	Initial Costs	Multiplier[a]	Oct. 1975 Costs	Carrying Charge[b]	Annual Costs	Cost Per DU Per Yr (656)[c]	Cost Per Cap. Per Yr (1713)[c]	Cost Per Cu Yd (12,300 cu yd per yr)[c]
Capital Costs:								
Storage pen[d]	$ 800	1.0914	$ 873	0.098	$ 86			
Refuse containers[e]	17,023	1.0914	18,579	0.146	2,713			
Refuse container enclosures and holding racks[f]	8,631	1.0914	9,420	0.179	1,375			
Two tractors[g]	4,680	1.0914	5,108	0.131	669			
Two trailers[g]	360	1.0914	393	0.079	31			
					$ 4,874	$ 7.43	$ 2.85	$0.40
Recurring Costs:								
City (Budget)[h]	$16,400	1.1228	$18,414	NA	$18,414	$ 28.07	$10.75	$1.50
Operation and Maintenance Costs:								
Labor (full time, site)[i]	$37,440	1.1228	$42,038	NA	$42,038			
Labor (part time, site)[j]	1,170	1.1228	1,314	NA	1,314			
Fuel, lubricants and maintenance for tractors and trailers	61	1.0914	67	NA	67			
Plastic bags[k]	2,795	1.0914	3,050	NA	3,050			
Hauling (private contractor)[l]	1,040	1.0914	1,135	NA	1,135			
					$47,604	$ 72.57	$27.79	$3.87
Total Annual Costs:					$70,892	$108.07	$41.39	$5.77

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a - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.

b - The carrying charge is interest plus sinking fund factor. See Section I for explanation.

c - Occupancy was 651 dwelling units. The number of residents and the observed volume of refuse collected are multiplied by 656/651 to adjust to total site occupancy.

d - $800 initial cost for chain-link pen, twenty-year life (July 1974).

e - 587 containers at $29 each, ten-year life (July 1974).

f - 63 at $73 each, 64 at $63 each, 7.5-year life (July 1974).

g - Tractors at $2600 each, four-year life. Trailers at $200 each, forty-year life, 90 percent of use is for refuse collection on-site (July 1974).

h - City budgets $25 per dwelling unit per year from general revenue funds for refuse collection (July 1974).

i - Four men at 48 hours per week (each) at $3.75/man-hour including 20% fringe benefits (July 1974).

j - Nine man-hours per week at $2.50/man-hour including 20% fringe benefits (July 1974).

k - Use 5000 bags every eight weeks at cost of $8.60 per 100 bags (July 1974).

l - Two 30-cu yd containers per week at $10 per container (July 1974).

Table 27. SUMMARY OF TOTAL COST OF REFUSE COLLECTION AND DISPOSAL AT LA CLEDE TOWN IN ST. LOUIS

(October 1975 basis)

	Annual Costs	Cost per DU/yr (1120 units)	Cost per Cap./yr (2708 people)	Cost per cu yd (15,100 cu yd per year)
Capital Costs:	$ 24,956	$ 22.28	$ 9.22	$1.65
Recurring Costs:	$ 31,438	$ 28.07	$11.61	$2.08
Operation and Maintenance Costs:	$ 68,147	$ 60.85	$25.17	$4.51
Total Annual Costs:	$124,541	$111.20	$46.00	$8.24

Table 28. ANNUAL EXPENSES FOR COST ELEMENTS OF REFUSE COLLECTION AND DISPOSAL AT THE ST. LOUIS SITE

(October 1975 basis)

	Municipal (estimated)	Private (estimated)	Site	Segment Total	Percent of Annual Total
Capital Costs:					
Truck	$ 1,886	$ 204		$ 2,090	2%
Compactors and containers			$19,609	19,609	16
Storage pens			433	433	-
Containers, enclosures, racks			4,088	4,088	3
Tractors and trailers			826	826	1
	$ 1,886	$ 204	$24,956	$27,046	22%
Recurring Costs:					
Licenses, insurance, taxes	$ 314	$ 68		$ 382	-
Operation and Maintenance Costs:					
Labor	$ 6,602	$ 715	$46,855	$54,172	43%
Fuel, lubricants, maintenance	629	35	7,482	8,146	7
Disposal fees	22,007	2,383		24,390	20
Plastic bags			10,405	10,405	8
	$29,238	$3,133	$64,742	$97,113	78%
Totals:	$31,438	$3,405	$89,698		
Annual Total:	$124,541				100%

Technical Analysis

The collection and disposal of refuse at the St. Louis site was observed for three days. Based on the estimated volume of observed refuse and discussions with site personnel, the estimated refuse collected is 286 cu yd per week for 1098 occupied dwelling units, equivalent to 14,880 cu yd per year. Considerable data for refuse collection and disposal were collected for the St. Louis site and discussed in the following paragraphs.

La Clede Town -

The refuse service to La Clede Town consists of a tractor driver and three men. The three men remove plastic trash bags from containers located along sidewalks and alleys throughout the site. They reline the containers and set the bags curbside. The tractor driver loads bags onto the trailer and helps with removing bags and relining containers. The distance between services averages about 80 feet when the driver moves the tractor around the site. Some containers are not located curbside, but the bagged refuse is set curbside by the three men who remove filled bags and reline containers. The refuse is picked up six days each week. The refuse collection performance is reflected in the following observed and calculated results:

(Average week -- 6 days)

	Distance Travelled (Miles)	Trailer Loads	Cubic Yards	Number of Men	Elapsed Time (Min.)
Monday	7.5	5	50	4	480
Tuesday	4.5	3	30	4	480
Wednesday	4.5	3	30	4	480
Thursday	5.2	3.5	35	4	480
Friday	5.2	3.5	35	4	480
Saturday	4.5	3	30	4	480

Refuse Collection Parameters at La Clede Town

Per Mile Travelled	Per Mile Through the Site	Per Man-Hour	Per Hour
6.69 cu yd	105 cu yd	1.1 cu yd	4.4 cu yd
64.01 plastic bags	1005 plastic bags	10.5 plastic bags	41.9 plastic bags
12.96 cartons	203.5 cartons	2.1 cartons	8.5 cartons
120.57 residences	315.5 residences	19.7 residences	78.9 residences

Operation Breakthrough Site -

East Site - Two men using a tractor and trailer spend two hours, two days per week emptying 19 containers for the MFLR and MFMR dwelling units. The containers are receptacles for refuse compacted by residents who have individual household compactors. Paper bags are used which are specifically designed for the compactors. The bags are stored in a pen where city refuse service makes pickups.

Two men spend 30 minutes, two times per week, replacing compactor containers in the MFHR building and rolling the full 2-cu yd container to the parking lot where a private hauling company can empty the container into an overhead (front loader) packer truck. The chute in the MFHR blocks up about two times a week requiring one man-hour to clear. Refuse collection performance results are given below for the East site:

Distance travelled	about 2400 feet/day (2 days per week)
Cu yds of refuse (MFLR/MR)	1/2 cu yd/wk (40% compacted)
Cu yds of refuse (MFHR)	4 cu yd/wk (40% compacted)
Total refuse (loose)	17.1 cu yd/wk
No. of men (site personnel)	2
Man-time (site personnel)	2 man-hours/week
Elapsed time (site personnel)	1 hour/week
No. of residences	241 dwelling units
Occupancy	232 dwelling units

West Site - The SFA units are serviced by one man one hour per day, five days per week, to pickup refuse and store in a pen or curbside. Most refuse is stored curbside where the La Clede Town crew picks up the refuse and stores it in the central pen for city pickup or to be disposed by private service.

The residents in the MFLR units carry compacted refuse to containers next to buildings. Site personnel move refuse to locations where the private contractor can pickup and dispose of wastes. Two men spend 30 minutes, two times per week, to pickup refuse and move 2-cu yd containers to areas accessible to the private hauler's truck.

Two men spend 30 minutes, two times per week, replacing compactor containers in the MFHR building and rolling the full container to the parking lot where a private hauling company can empty the container into an overhead (front loader) packer truck. The MFHR refuse chute blocks up about twice per week requiring one man-hour to clear. Refuse collection performance results are given below for the West site:

Distance travelled	about 2,000 feet/day (2 days/week)
SFA refuse	1/4 cu yd/wk (40% compacted)

MFLR refuse	4 cu yd/wk (40% compacted)
MFHR refuse	4 cu yd/wk (75% compacted)
Total refuse (loose)	34.0 cu yd/wk
No. men	3
Man-time	10 man-hours/wk
Elapsed time, SFA	5 hours/wk
Elapsed time, MFLR/MFHR	4 hours/wk
No. of residences	223 dwelling units
Occupancy	215 dwelling units

East and West Portions Combined -

Distance travelled	about 8800 ft/wk
Total loose refuse	55.1 cu yd/wk
No. of men	5 (at different intervals)
Man-time	12 man-hours/wk
Elapsed time	10 hours/wk
Occupancy	447 dwelling units

Refuse collection performance is reflected in the following results:

• Refuse collected per mile travelled	30.6 cu yd/mile
• Refuse collected per man-hour of collection time	4.3 cu yd/man-hour
• Refuse collected per hour of collection time	5.1 cu yd/hour
• Refuse collected per residence (occupied)	0.1 cu yd/residence
• Residences per mile travelled	268.2 res./mile
• Residences per man-hour of collection time	37.2 res./man-hour
• Residences per hour of collection time	44.7 res./hour

La Clede Town Plus Operation Breakthrough Site -

Distance travelled	33.1 miles/wk
Distance through site	13.7 miles/wk
Total loose refuse (residences)	266.1 cu yd/wk
Total yard refuse	20 cu yd/wk
Total refuse	286 cu yd/wk
Man-time	204 man-hours/wk
Elapsed time	58 hours/wk
Occupied residences	1098 dwelling units

Refuse collection performance for the entire site is reflected in the following results:

• Refuse collected per mile travelled	8.6 cu yd/mile
• Refuse collected per mile through site	20.9 cu yd/mile
• Refuse collected per man-hour of collection time	1.4 cu yd/man-hour
• Refuse collected per hour of collection time	4.9 cu yd/hour
• Refuse collected per dwelling unit (occupied)	0.3 cu yd/unit/wk
• Dwelling units serviced per mile travelled	32.6 du/mile
• Dwelling units serviced per man-hour of collection time	5.3 du/man-hour
• Dwelling units serviced per hour of collection time	18.6 du/hour

Refuse Pickup by City and Private Contractor -

In addition to on-site refuse collection, municipal disposal and private disposal services are used at the site. Refuse compacted into 2-cu yd containers in the MFHR buildings are picked up by front loader trucks, privately contracted. Additionally, when municipal service is not sufficient for pickup at La Clede Town, a private contractor is called, who brings in a 30-cu yd roll-off container which is filled by three site personnel. When filled, the private contractor removes the container.

During the observation period, St. Louis municipal refuse services were hampered by the effects of a work strike by their employees. A large amount of refuse was piled in the La Clede Town pen which was decaying, causing odors (and complaints by residents), attracting flies, and presenting a bad aesthetics problem. Site management stated that daily city pickup operations when normal eliminate most of the refuse accumulation problem, but hot weather still causes problems with odors and flies. Also, at the time of observation, the 30-cu yd container was being hauled away twice a week which was not sufficient to remove all refuse from the pen.

Collection Times -

Producting and nonproductive collection time are estimated man-times per average day for various collection activities

La Clede Town (refuse collection):

	Tractor Driver (Man-min)	Three Other Men (Man-min)	Avg. Per Day Total (Man-min)
Tractor:			
Riding	62.4	0	62.4
Plastic Bag Handling	60.7	957.5	1018.2
Walking	3.8	317.3	321.1
Set Curbside	0	55.1	55.1
Loading	101.8	0	101.8
Unloading	30.6	0	30.6
30-cu yd Container:			
Loading	0	85.0	85.0

Total man-time = 1674.2 man-minutes per day x 6 = 10,044.3/wk
or 10,044.3 man-minutes per week x 52 = 522,303.6/yr

The type of effort involved where three men move through the site independent of tractor and trailer results in practically no nonproductive time. On light days (Tuesday, Wednesday, and Saturday), the crew may finish on-time or a little early. On Mondays, the crew may finish late. On Thursday and Friday, the crew finishes on time.

Operation Breakthrough Site (avg. per day for a week, six working days):

Riding	30 man-minutes
Walking (set curbside)	10 man-minutes
Loading	20 man-minutes
	60 man-minutes/day, or
	360 man-minutes/week

Entire Site (avg. per day for a week, six working days):

	Per Day (Man-min)	Per Week (Man-min)	Per Year (Man-min)
Riding	92.4	554.5	28,831.9
Plastic Bag Handling	1,018.1	6,108.8	317,656.6
Walking	321.0	1,926.2	100,164.5
Set Curbside	65.1	390.5	20,308.1
Loading	206.8	1,240.5	64,506.0
Unloading	30.6	183.8	9,556.6
	1,734.0	10,404.3	541,023.7

In the following paragraphs, the above technical data and qualitative observations are discussed relative to equipment performance, site appearance, and environmental aspects.

Equipment Performance -

Suitability - A better arrangement should be considered for La Clede Town. Excessive handling and storage in open pens are unsuitable aspects of the refuse system. The compactor equipment in the Operation Breakthrough portions of the site appears to be a very suitable approach for refuse handling; however, the excessive handling of refuse decreases suitability. Excessive handling of refuse is a system deficiency at the site. For SFA, MFLR, and MFMR units, residents place refuse in containers, site personnel empty containers and place refuse in storage pens, the city services the pens and disposes the refuse off site. A study of direct pickup and disposal by site personnel could result in reduced overall costs and increased system suitability.

Effectiveness - Lost time or nonproductive time is minimal; however, the refuse system is labor intensive. Site personnel collect an average of 1.4 cu yd per man-hour. Assuming the labor requirements could be reduced to the point where a more typical value of 16 cu yd per man-hour were expended (comparable to an average of the King County curbside service and the Macon container service), the estimated site costs per cu yd of refuse could be reduced by \$3.27 per cu yd to \$4.97 per cu yd. Comparing the reduced costs with the actual value, the effectiveness with respect to costs is:

$$\left[1 - \left(\frac{8.24-4.97}{4.97}\right)\right] \times 100 = 34 \text{ percent}$$

Under the comparison conditions, the site effectiveness is very low.

The compactors on the Operation Breakthrough portions of the site have performed well and appear effective except for capital and the maintenance costs. The MFHR compactors are used effectively and account for \$7,589 in annual costs. The household compators are not very effective and they account for \$15,637 in annual capital costs and \$6,063 in annual operating and maintenance costs (excluding \$7,355 per year for compactor bags). The \$29,055 annual expense for household compactors represents 23 percent of the total annual site costs. The bags of refuse from household compactor units were not all compacted. From observations over a three-day period, about forty percent of the bags appeared to have been compacted. Loose refuse was in the other sixty percent of the bags. It is concluded that household compactors on the site are not effectively utilized. If they were, refuse could probably be collected only once a week from the areas having household compactors thereby reducing site labor requirements and costs.

Resident Acceptance - The residents use the refuse system. The only complaints received by site management involve odors and insects at the storage pens. The methods of collection and disposal appear to be very convenient for use by the residents. A survey of residents was not made at the St. Louis site as at other sites; therefore, resident attitudes toward refuse collection are not known. It can be stated that the full capacity of the household compactors is not being utilized which results in the requirement for more pickups from the containers by site personnel.

Site Appearance -

The site appearance is excellent and very little litter is noticeable around the site. The refuse pen for La Clede Town was very messy during the three-day observation period. Municipal refuse personnel were on-strike and a considerable volume of refuse was stored in the pen. The refuse was noticeable but only in the area of the pen. Except for the piled up refuse, all three pens blend nicely into the site surroundings. The containers in the MFLR, MFMR, and MFHR buildings are hidden from view by enclosures that are built into and match the exterior of the buildings.

Environmental Considerations -

Refuse stored in open pens is subject to the effects of exposure to the weather. The refuse decays, causes odors, attracts flies and other insects, and may present sanitation problems. Hot weather causes extreme problems with odors, flies, and other insects. It may also be presumed that the open pens provide feeding areas for vermin.

Results

The results are presented as the advantages and disadvantages of the St. Louis site refuse collection system in economics, effectiveness, efficiency, and environmental aspects.

Economic Advantages -

The high rise chute-fed compactors are economical. There are no other economic advantages of the system at the site.

Economic Disadvantages -

Costs are excessive for the entire site. The costs for the Operation Breakthrough portion of the site are higher than the costs for the La Clede Town portion on a per unit volume of refuse collected due to ineffective use of household compactors. The excessive labor expenditures are major contributors to high costs at the site.

Effectiveness, Advantages -

The Operation Breakthrough portion of the site could be effective if residents would use the household compactors and refuse was picked up only once a week.

Effectiveness, Disadvantages -

The refuse collection system is very labor intensive, using 36.4 man-minutes per cu yd of refuse. There is too much handling of refuse at the site.

Efficiency, Advantages -

Nonproductive time is minimal, but excessive handling of refuse is required.

Efficiency, Disadvantages -

Excessive labor requirements and handling of refuse are required. The La Clede Town containers are emptied six times a week and 42.7 man-minutes are expended per cubic yard of refuse collected. The Operation Breakthrough portion of the site requires 7.0 man-minutes per cubic yard of refuse collected. The inefficiency results from handling the refuse many times. Curbside pickup would benefit the La Clede Town portion of the site by eliminating the need to place refuse in containers and then move refuse from containers to street areas for pickup. Similarly, the refuse is then placed in pens to await pickup and disposal by the municipal service and by private contractors. A recommended improvement is to eliminate excessive handling of the refuse by curbside pickup and direct disposal by site, private, or city personnel.

Environmental Advantages -

Site aesthetics are excellent around the buildings.

Environmental Disadvantages -

Sanitation may be a problem in the vicinity of the storage pens. The storage pens are open to weather effects. Decaying refuse in pens is aesthetically unappealing, causes odors, and attracts insects and possibly vermin. Also, excessive handling of the bagged refuse causes bag tears and refuse spillage which increases the probability that storage problems occur.

SEATTLE, WASHINGTON

The Seattle site was visited April 18, 21, and 22, 1975. The refuse management system consists of a combination of four one-cu yd containers in an outside enclosed (open top) pen and two refuse chutes. Each of the chutes feeds four one-cu yd containers located inside refuse rooms adjacent to the underground parking garage for the site. One chute is located outside with a charging station at ground level. The other chute is located in a community center adjacent to SFA units with charging stations on the second and third levels. The containers and collection method are depicted in Figures 31 through 35. The site arrangement is shown in Figure 36, and demographic and other data are given in Table 29.

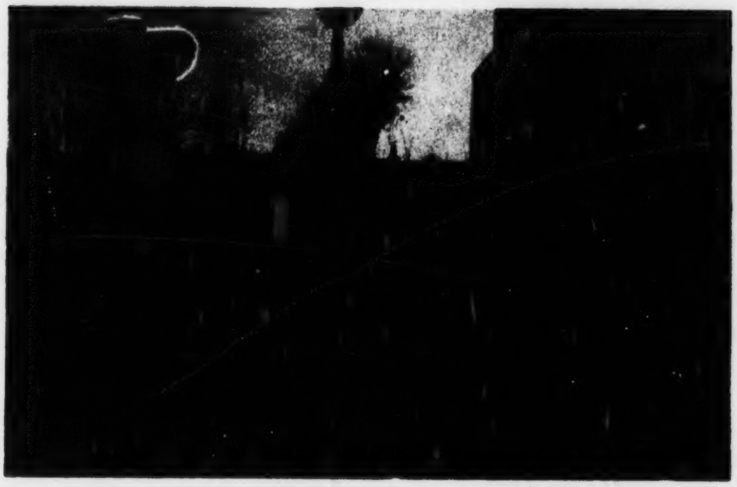

FIGURE 31. Enclosure for four one-cu yd containers at the Seattle site. The enclosure is located beside building.

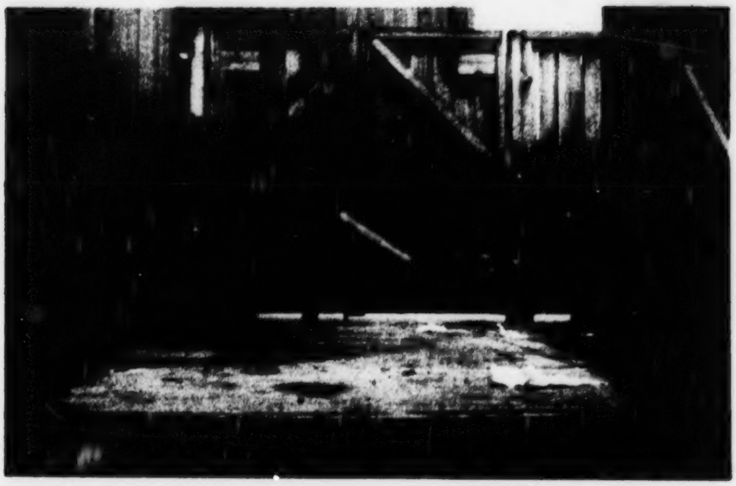

FIGURE 32. Internal picture of enclosure at the Seattle site. Three containers are out of view to the right.

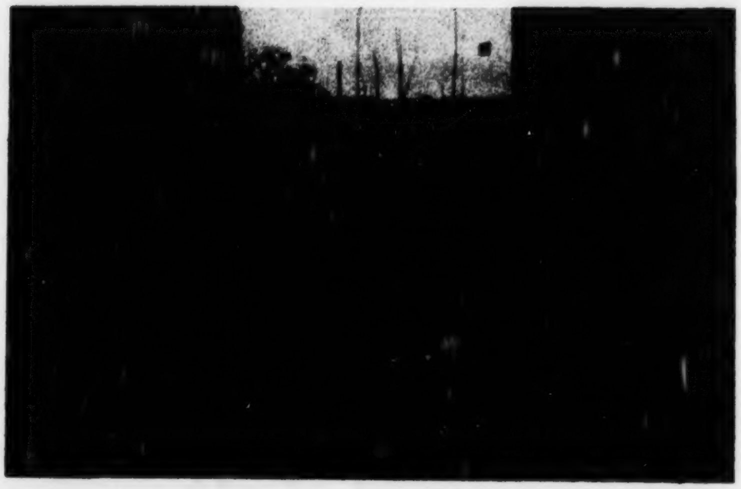

FIGURE 33. One-cu yd container from chute-fed refuse rooms awaiting pickup at the Seattle site.

FIGURE 34. Closeup of one-cu yd containers from chute-fed refuse room at the Seattle site.

FIGURE 35. Refuse collection at the Seattle site using a rear-loading packer truck. The containers are rolled to the truck, emptied, and returned.

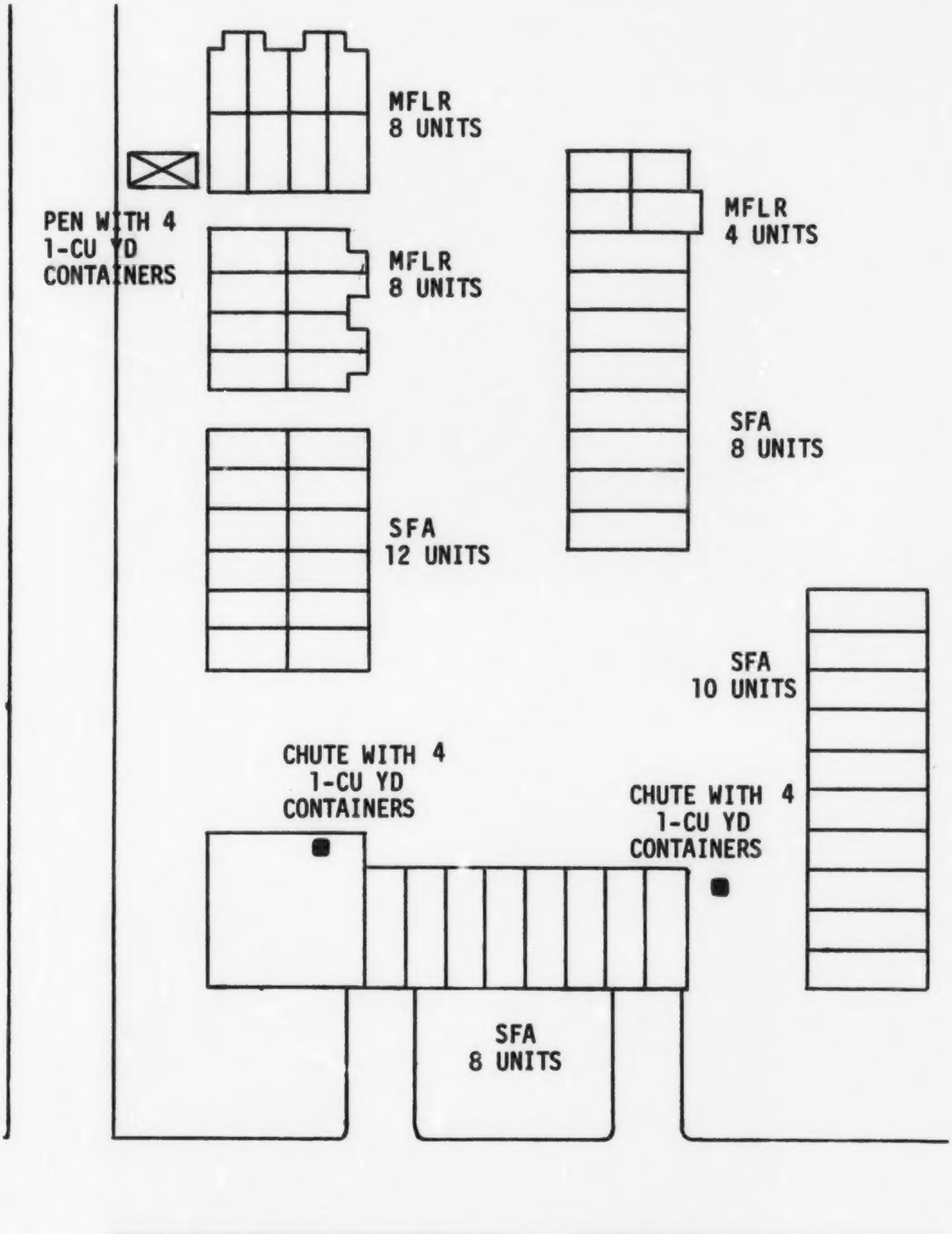
MFLR
8 UNITS
MFLR
4 UNITS
PEN WITH 4
1-CU YD
CONTAINERS
MFLR
8 UNITS
SFA
8 UNITS
SFA
12 UNITS
SFA
10 UNITS
CHUTE WITH 4
1-CU YD
CONTAINERS
CHUTE WITH 4
1-CU YD
CONTAINERS
SFA
8 UNITS

FIGURE 36. Seattle Operation Breakthrough site arrangement showing location of refuse chutes and containers.

Table 29. DEMOGRAPHIC AND SOLID WASTE SYSTEM DESCRIPTIVE DATA FOR THE SEATTLE OPERATION BREAKTHROUGH SITE

Number and type of dwelling units and occupancy:

Type	No.	Vacancies	Residents
MFLR	20	19	50
SFA	38	1	156

Number occupied = 56 units
Number residents = 206 people
Site area = 1.8 acres

Distribution of units to each refuse service point:

23 SFA units use 2 chutes feeding one-cu yd containers
35 SFA and MFLR units use four one-cu yd containers located in the enclosure

Average number of units per service = 19.7
Average number of people per service = 68.7

Refuse System Description

The residents of the Seattle site deposit their refuse in refuse chutes or in enclosed containers. Site personnel replace full containers with empty containers under each chute on a daily basis. Site personnel move the chute-fed containers to the curbside twice a week for pickup by a municipally contracted pickup service. Four one-cu yd containers are located at each of the three services. The pickup contractor moves containers from the enclosure to empty. The contractor uses a rear-loading packer truck with a driver and two helpers to collect refuse. The site is serviced twice a week, and other urban areas are serviced before and after servicing the site.

Economics Analysis

The economic data are tabulated in Table 30 in general form. The refuse pickup and disposal costs account for 78 percent of the costs in the system. The pickup and disposal costs are fixed by city ordinance and are collected by the city. The costs of various elements of the pickup service are estimated from data obtained from discussions with city personnel and the contractor and observation of the collection at the site. The resulting costs of various elements of the refuse collection system are shown in Table 31. Labor costs and disposal fees account for 70 percent of the refuse system expenses to the site.

Table 30. COST OF REFUSE COLLECTION AND DISPOSAL AT THE SEATTLE OPERATION BREAKTHROUGH SITE

	Initial Costs	Multiplier[a]	Oct. 1975 Costs	Carrying Charge[b]	Annual Costs	Cost Per DU Per Yr (58)[c]	Cost Per Cap. Per Yr (213)[c]	Cost Per Cu Yd (850 cu yd/yr)[c]
Capital Costs:								
Refuse chutes (40-year life)	$3,640	1.0618	$3,865	0.079	$ 305			
Enclosed pen (7.5-year life)	323	1.0618	343	0.179	61			
					$ 366	$ 6.31	$ 1.72	$0.43
Recurring Costs:[d]	$ 0		$ 0	NA	$ 0	$ 0	$ 0	$ 0
Operating and Maintenance Costs:								
Labor[e]	$ 627	1.0763	$ 675	NA	$ 675			
Refuse pickup and disposal charges[f]	3,471	1.0618	3,686	NA	3,686			
					$4,361	$75.19	$20.47	$5.13
Total Annual Costs:					$4,727	$81.50	$22.19	$5.56

---

[a] - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.

[b] - The carrying charge is interest plus sinking fund factor. See Section I for explanation.

[c] - Occupancy was 56 dwelling units out of 58 dwelling units on the site. The number of residents and the observed refuse collected are multiplied by 58/56 to adjust to total site occupancy.

[d] - Costs of all refuse management for the city is borne by the refuse rate structure as provided in a city ordinance.

[e] - Site personnel at $5.48 per hour, 2 hours per week, plus 10 percent fringe benefits (April 1975).

[f] - City collects charges of $289.25 per month based on emptying twelve containers, twice a week (April 1975).

Table 31. ESTIMATED ANNUAL EXPENSES FOR SEGMENTS OF THE REFUSE COLLECTION AND DISPOSAL AT THE SEATTLE SITE

	City and Private	Site	Segment Total	Percent of Annual Total
Capital Costs:				
Truck	$ 221		$ 221	5%
Containers	700		700	15
Refuse Chutes		$ 305	305	6
Enclosed pen		61	61	1
	$ 921	$ 366	$1,287	27%
Recurring Costs:				
Licenses, Insurance, Taxes	$ 37		$ 37	1%
Operating and Maintenance Costs:				
Labor	$1,253	$ 675	$1,928	41%
Fuels, lubricants, maintenance	111		111	2
Landfill Cost	1,364		1,364	29
	$2,728	$ 675	$3,403	72%
Totals:	$3,686	$1,041	$4,727	100%
Annual Total:	$4,727			

The site costs are $22.19 per capita per year as compared to $12.08 in the adjusted national average for refuse collection and disposal. The costs at the Seattle site are higher than the national average. A comparison of the costs shows the Seattle site expending $1.72 per capita per year for capital costs and $20.47 per capita per year for operation and maintenance as compared to the adjusted national averages of $3.04 per capita per year for capital costs and $9.04 per capita per year for operation and maintenance costs.

Technical Analysis

An estimated 15.8 cu yd of refuse are collected each week from the Seattle site. The technical data for refuse collection and disposal are summarized in Table 32 including actual observations of the distance travelled, number of stops, dwelling units serviced, crew size, refuse collected, estimated volume, elapsed time, and labor time expenditures. Waiting time is considered nonproductive time and is 22 percent of the total labor spent in refuse collection activities.

Equipment Performance -

Suitability - The system design is very suitable and the equipment is fully used and very satisfactory. There is very little littering because the system is convenient and easily cleaned.

Effectiveness - The system is very effective. Methods to decrease cost could only occur if it were possible to slightly change the service requirement. The four containers in the enclosed pen must be serviced twice a week. The chute-fed containers in refuse rooms could be serviced on a once a week basis since the refuse is protected from weather, is enclosed, and is not subject to causing odors in hot weather. The refuse from the chutes could be handled by once a week pickup with four one-cu yd refuse containers provided under the refuse chute inside the community center. The refuse from the outside chute could be handled by once a week pickup with six one-cu yd refuse containers provided. The costs of the pickup service would be reduced to $2,977 per year representing a savings of $708 per year. Assuming this change were made, the resulting cost of collection and disposal is $4.73 per cu yd. A comparison with the achieved costs gives a high estimated effectiveness of 92 percent:

$$\left[1 - \left(\frac{5.13-4.73}{4.73}\right)\right] \times 100 = 92\%$$

Table 32. OBSERVED REFUSE COLLECTION ACTIVITIES AT THE SEATTLE SITE FOR ONE WEEK WITH PROJECTIONS TO ONE YEAR WITH ANALYTICAL RESULTS

NOTE: The site is serviced twice a week.

							Time Elements				
Service	Distance Traveled	No. of Stops	No. of Units	Crew Size	Items Collected	Estimated Volume	Elapsed	Time Riding	Walking Handling	Waiting Packing	Total Man-time
Site Personnel:											
		4	56	1	10 containers	15.8 cu yd	1080 seconds	0	1080 man-seconds	0	1080 man-seconds
Private Service Contractor:											
	0.6 miles	9	56	3	18 containers	15.8 cu yd	660 seconds	270 man-seconds	2450 man-seconds	1060 man-seconds	3720 man-seconds
Total per year	31 miles	468 stops per yr	56 units served		936 containers	822 cu yd	25 hours	3 man-hours	51 man-hours	15 man-hours	69 man-hours

Analytical Results

Average distance per stop (3):	0.03 miles per stop
Average labor per stop (3):	26.5 man-minutes per stop
Average dwelling unit density per stop (3):	18.7 dwelling units per stop
Average labor per cu yd:	5.0 man-minutes per cu yd
Riding:	0.2 man-minutes per cu yd
Walking/Handling:	3.7 man-minutes per cu yd
Waiting/Packing:	1.1 man-minutes per cu yd

Resident Acceptance - Residents use the system very effectively and appear to accept the system. A resident survey was conducted and a separate report[2] presents the results. In general, the survey concluded that the collection and disposal system is adequate with 95 percent of the respondents giving favorable responses; however, over half of the respondents indicate potential personal hazards, primarily from falls and criminal assaults, in the use of the enclosed storage area. Site management expressed no overall opinion about suitability, problems, or resident cooperation. Site management did not mention any personal hazard occurrences.

Site Appearance -

The site appearance is excellent with respect to effects from the refuse collection and disposal system as shown in Figure 31. The only littering due to refuse facilities appeared inside the enclosed storage pen and was minor (see Figure 32).

Environmental Considerations -

Site appearance is excellent. In hot weather, residents have complained of odors from containers in the enclosed pen. No sanitation problems are apparent. Noise levels when refuse is collected are negligible to the site.

Results

The results are presented as the advantages and disadvantages of the Seattle refuse collection system in economics, effectiveness, efficiency, and environmental aspects.

Economic Advantages -

Capital expenditures for the refuse system are low at $366 per year. There are no direct recurring costs.

Economic Disadvantages -

Refuse pickup and disposal costs are high at $3,686 per year which is 78 percent of the total annual costs. These costs could probably be reduced by once a week service to the chute-fed containers. Such a change should not cause any detrimental environmental effects to the site.

Effectiveness, Advantages -

Very little handling of refuse is necessary, and the system is very effective. The cost effectiveness could be improved by once a week service of the chute-fed containers. Chute containers are in locked rooms out of sight and safe from vandalism. There should be no adverse effects from once a week service.

Efficiency, Advantages -

The system operates very efficiently and requires minimal efforts from site personnel. The non-productive time expenditures are low, and the system achieves 78 percent productive utilization of labor time.

Efficiency, Disadvantages -

A three man collection crew was used and probably a one or even two-man crew could satisfactorily empty the containers. Waiting time occurs during truck compaction cycles and the larger the crew size the higher the waiting time accrued. Waiting time is non-productive and decreases the efficiency. It is the collection crew waiting time that keeps the labor utilization efficiency at 78 percent instead of a much higher value. The efficiency of the collection crew could be improved at the site if a one or two-man crew was used in place of the three-man crew; however, this reduction may not be possible due to requirements for personnel when servicing urban areas other than the Operation Breakthrough site.

Environmental Considerations -

Advantages - The site appearance is excellent. Litter from the refuse system is contained in the enclosed pen. The noise during collection activities is minimal. There are no apparent sanitation problems.

Disadvantages - Odors are prevalent in hot weather in the enclosed pen which also suggests the possibility of insect attraction.

SACRAMENTO, CALIFORNIA

The Sacramento site was visited on April 28, 29, and 30, 1975. The refuse management system consists of chute-fed containers in two MFHR buildings, trash cans inside redwood pens for MFLR units and one SFA section, and backyard pickup from the remainder of the site which includes SFA and SFD units. The chute-fed containers, pens, and collection methods are depicted in Figures 37 through 41. The site arrangement is shown in Figure 42. The site demographic and other data are given in Table 33.

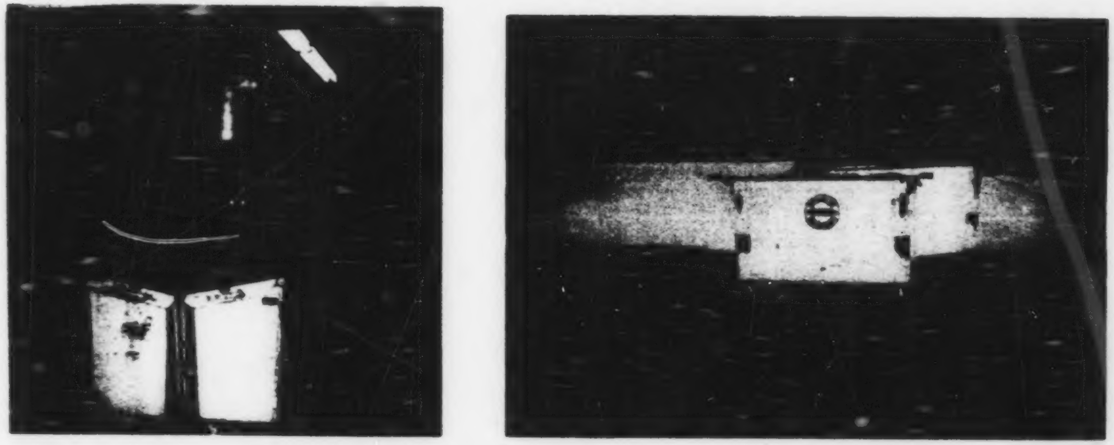

FIGURE 37. Typical chute-fed container installations in the MFHR building at the Sacramento site (left photograph). The right photograph shows two containers set curbside for pickup.

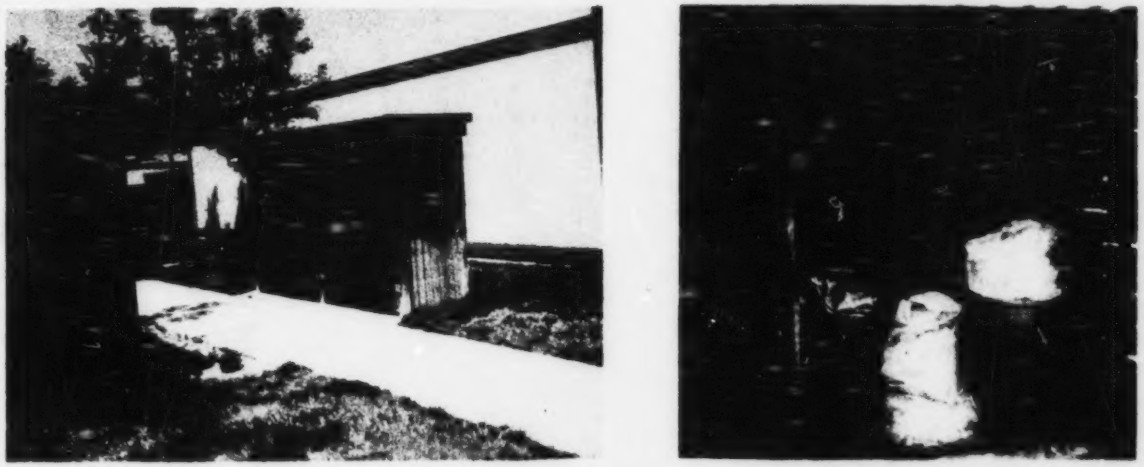

FIGURE 38. Typical of ten redwood pens and trash cans as used for the MFLR section and one SFA section of the Sacramento site. The left photograph is one of nine four-can pens. The site has one six-can pen. The photograph at right shows one-half of a four-can unit on day before pickup.

FIGURE 39. Typical backyard area of SFA units which are serviced with backyard pickup at the Sacramento site.

FIGURE 40. Two rear-loading packer vehicles and crew which serviced the MFLR and most of the SFA units at the Scaramento site. Note the tote cans for collection and carrying refuse.

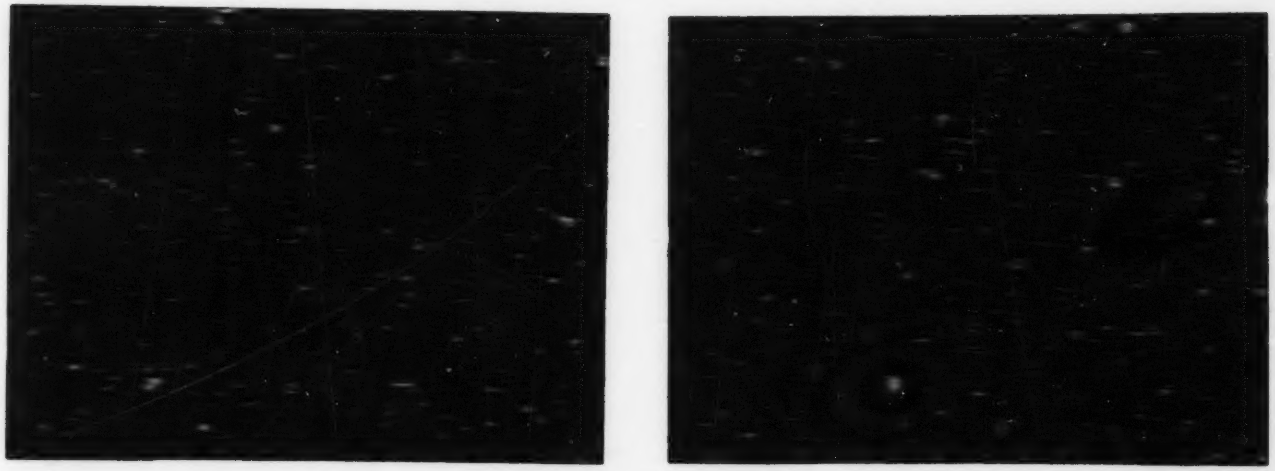

FIGURE 41. Box and cart which is used for refuse collection from backyards of one SFA section at the site. The collected refuse is placed in the containers in the MFHR building and the box is reused.

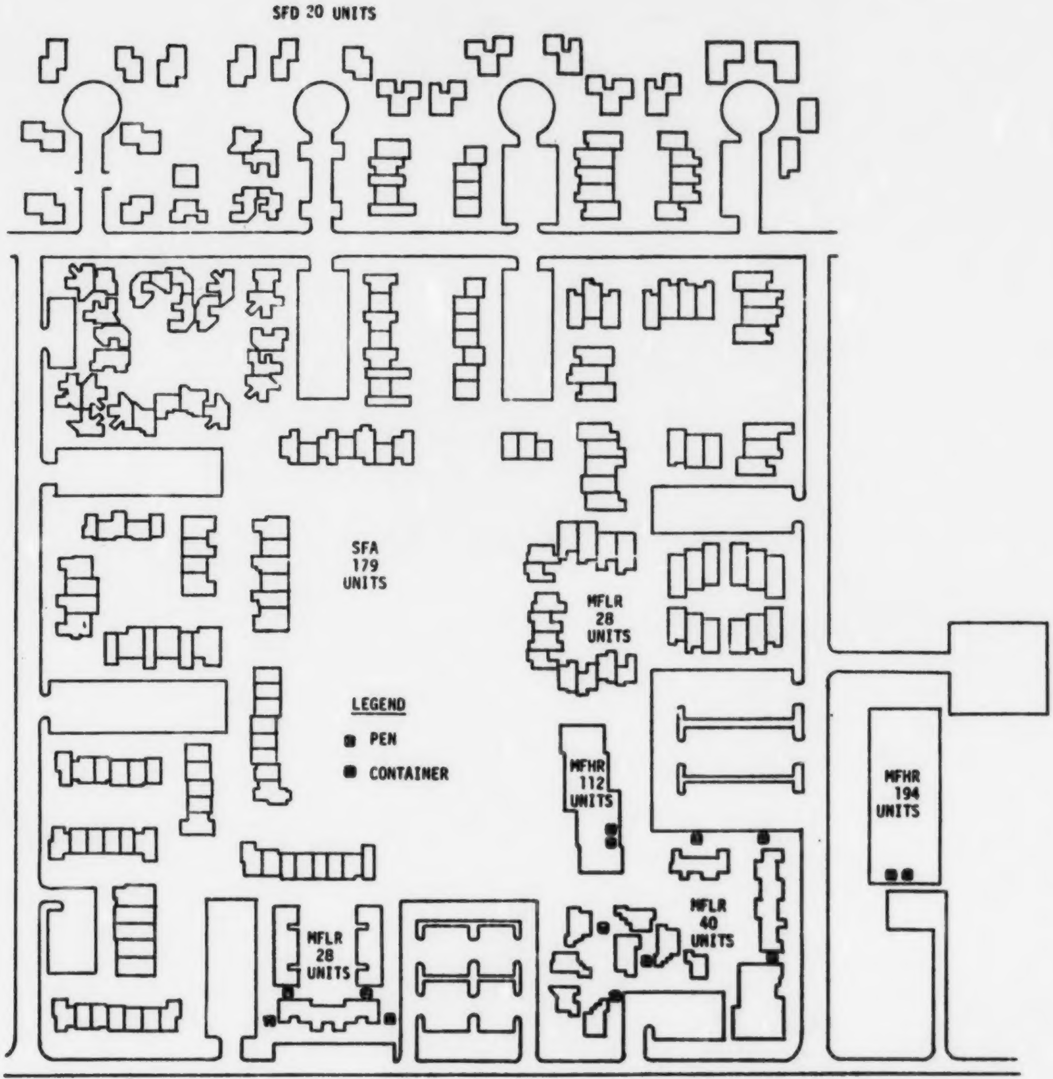
SFD 20 UNITS
SFA 179 UNITS
MFLR 28 UNITS
LEGEND
■ PEN
■ CONTAINER
MFHR 112 UNITS
MFHR 194 UNITS
MFLR 40 UNITS
MFLR 28 UNITS

FIGURE 42. Sacramento Operation Breakthrough site arrangement showing location and type of services.

Table 33. DEMOGRAPHIC AND SOLID WASTE SYSTEM DESCRIPTIVE DATA FOR THE SACRAMENTO OPERATION BREAKTHROUGH SITE

Number and type of dwelling units and occupancy:

Type	No.	Vacancies	Residents
SFA	179	18	724
SFD	20		
MFLR	96	1	178
MFHR	306	0	336

Number occupied: 582 units
Number residents: 1238 people

Distribution of units to each refuse service point:

28 MFLR seven days per week backyard service by site personnel. Refuse is moved on a cart and placed in containers inside MFHR building.

68 MFLR once a week municipal service from trash cans in enclosed pens.

179 SFA once a week backyard municipal service.

20 SFD once a week backyard municipal service.

306 MFHR six days a week municipal service to six containers.

Refuse System Description

Residents of the two MFHR buildings (306 units) remove boxes and newspapers and place the remaining refuse into chutes which feed two-cu yd containers (see Figure 37). Newspapers and boxes are placed in the charging station closets on each floor for collection each day by site personnel. Three two-cu yd containers are provided in each MFHR buildings. Two containers from each building are emptied each morning, Monday through Saturday, by a municipal front loading packer truck. Site personnel maintain refuse room cleanliness and change containers under the chutes.

Residents of 28 MFLR units have refuse picked up from their yards in the mornings, Monday through Saturday, by a site employee who hauls the refuse to a MFHR building and places the refuse in one of the containers (see Figure 41).

Residents of 68 MFLR units place their refuse in 42 trash cans located four to a pen in nine enclosed redwood pens and six in a tenth pen. The pens are located near parking lots and along sidewalks (see Figure 38). The cans are emptied once a week by a municipal service using a rear loading packer truck (see Figure 40).

Residents of 179 SFA and 20 SFD units place refuse into cans or bags located in areas provided in the courts in back or front of their homes. The city provides backyard pickup services to empty the cans once a week (see Figures 39 and 40). Two rear loading packer trucks are used with a total crew size of three men.

Based on observations for one day, approximately 101.6 cu yd of loose refuse are collected from the 582 dwelling units and disposed. For a total unit occupancy of 601 dwelling units, the volume of refuse would be estimated as 105.8 cu yd per week or about 5500 cu yd per year.

Economic Analysis

The economic data are given in Table 34 in general form. The city collection and disposal fees for the site account for for 71 percent of the annual costs to the site. The cost elements making up the city fees were not furnished by the city; therefore, the cost elements are estimated from data obtained from discussions with city personnel and observations of refuse collection and disposal. The estimated expenses of the elements are shown in Table 35. The labor costs and dump fees are estimated to account for 79 percent of the costs associated with refuse system at the site. The Sacramento site costs are $11.34 per capita per year versus the national average of $12.08 per capita per year.

Technical Analysis

The technical data collected during the three-day observation period are displayed in Table 36. The data are for the site at the 97 percent occupancy level. The estimated weekly volume of refuse is 101.6 cu yd which corresponds to an annual volume of about 5300 cu yd. The volume was estimated by counting tote-can loads placed on trucks by the crew and by observing the volume in the containers. There is no waiting time associated with the refuse collection methods. The crew loads refuse into the rear loading packing trucks, starts the packing cycle, and continues to collect refuse while the trucks are completing a packing cycle. Refuse is disposed in a city owned landfill. Crew

Table 34. COST OF REFUSE COLLECTION AND DISPOSAL AT THE SACRAMENTO OPERATION BREAKTHROUGH SITE

	Initial Costs	Multiplier[a]	Oct. 1975 Costs	Carrying Charge[b]	Annual Cost	Cost Per DU Per Yr (601)[c]	Cost Per Cap. Per Yr (1278)[c]	Cost Per Cu Yd (5500 cu yd per yr)[c]
Capital Costs:								
Refuse chutes (40-year life)	$3,960	1.0618	$ 4,205	0.079	$ 332			
Trash can enclosed pens (7.5-year life)	3,045	1.0618	3,233	0.179	579			
Trash cart (10-year life)	280	1.0618	297	0.146	43			
					$ 954	$ 1.59	$ 0.75	$0.17
Recurring Costs:	$ 0		$ 0	NA	$ 0	$ 0	$ 0	$ 0
Operating and Maintenance Costs:								
Labor, site[d]	$2,820	1.0763	$ 3,035	NA	$ 3,035			
Maintenance supplies	144	1.0618	153	NA	153			
City collection and disposal fees	9,742	1.0618	10,344	NA	10,344			
					$13,532	$22.51	$10.59	$2.46
Total Annual Costs:					$14,486 per year	$24.10 per DU per year	$11.34 per capita per year	$2.63 per cu yd

---

a - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.

b - The carrying charge is interest plus sinking fund factor. See Section I for explanation.

c - Occupancy was 582 dwelling units. The number of residents and the observed refuse collected are multiplied by 601/582 to adjust to total site occupancy.

d - 936 man-hours per year at $2.62 per hour plus 15 percent fringe benefits (April 1975).

Table 35. COMBINED SEGMENTS OF ANNUAL EXPENSES FOR REFUSE COLLECTION AND DISPOSAL AT THE SACRAMENTO SITE
(October 1975 Basis)

	Private	Site	Segment Total	Percent of Annual Total
Capital Costs:				
Trucks	$ 1,448[a]		$ 1,448	10%
Containers	207[a]		207	1
Refuse Chutes		$ 332	332	2
Trash can enclosed pens		579	579	4
Trash cart		43	43	1
	$ 1,655	$ 954	$ 2,609	18%
Recurring Costs:				
Licenses, Insurance	$ 207[a]	0	$ 207	1%
Operation and Maintenance Costs:				
Labor	$ 3,724[a]	$3,035	$ 6,759	47%
Fuels, lubricants, and maintenance supplies	103[a]	153	256	2
Landfill fees	4,655[a]		4,655	32
	$ 8,482	$3,188	$11,670	81%
Totals:	$10,344	$4,142	$14,486	100%
Annual Total:	$14,486			

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[a] - Estimated costs.

Table 36. OBSERVED REFUSE COLLECTION ACTIVITIES AT THE SACRAMENTO SITE FOR ONE PICKUP AND PROJECTIONS TO AN ANNUAL BASIS

							Time Elements				
Service	Distance Travelled		No. of Stops	No. of Units	Crew Size	Item Collected	Estimated Volume	Elapsed	Riding	Walking/ Handling	Waiting/ Packing	Total Man-Time
Municipal to MFHR (six times per week):												
	Drive: Walk:	0.25 miles 40 ft	2	306	2	4 containers	8 cu yd total	315 seconds	120 man-seconds	510 man-seconds	0	630 man-seconds
Municipal to MFLR, SFA, and SFD (one service per week):												
	Drive: Walk:	1.65 miles 47,543 ft	27	248	3	363 cans and bags	53.6 cu yd	6,975 seconds	990 man-seconds	17,676 man-seconds	0	18,666 man-seconds
Site personnel to MFLR and each floor of MFHR (seven times per week):												
	Walk:	1,200	32	28	1	7 bags	1.0[a] cu yd	3,600 seconds	0	3,600 man-seconds	0	3,600 man-seconds
Total per year	Drive: Walk:	164 miles 56,183 ft	13,676	582	see above	see above	5,300 cu yd per year	492 hours per year	25 man-hours per year	663 man-hours per year	0	688 man-hours per year

Analytical Results

Average distance per stop:	0.1 miles driving (39 stops/wk) personnel walk 3.1 ft per stop with 13,676 stops/yr.
Average labor per stop (39 stops/wk):	9.6 man-minutes per stop
Average dwelling unit density per stop (29):	20.1 dwelling units per stop
Average labor per cu yd:	7.8 man-minutes per cu yd

Riding: 0.3 man-minutes per cu yd
Walking/Handling: 7.5 man-minutes per cu yd
Waiting/Packing: 0 man-minutes per cu yd

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[a] The 1.0 cu yd per day is included in the refuse from the MFHR units.

time and distance to the landfill were not determined because additional refuse was collected at other urban locations after completion of a pickup at the site.

Equipment Performance -

Suitability - The equipment appear very suitable for the designed refuse system at the site. Only one problem was apparent. Some of the trash cans in the redwood pens become overloaded between pickups; however, some of the other cans were empty. Pen locations could have caused the problem. Proper location of the pens might provide better distribution of refuse among the cans.

Effectiveness - The effectiveness is good. It is doubtful that the costs could be reduced without altering the refuse system design. The overloading of some refuse pens might be eliminated by relocating some pens to supplement the pens in the heavily used areas.

Resident Acceptance - The residents use the system. Very little littering was visible. Residents utilizing two pens have complained about overloading of the trash cans. A separate report[2] presents the results of a survey of residents with regard to refuse management practices at the site. The survey indicates problems with refuse scattering, uncollected refuse, and a shortage of containers. Forty percent of the respondents in general feel that refuse storage and disposal is inadequate.

Site Appearance -

The site appearance with respect to the refuse system is excellent. Littering is minimal. The refuse pens blend into the site fairly well. Figures 37 through 41 show that site appearance in refuse equipment areas is excellent. The problems indicated in the survey of residents were not apparent when data were collected for the economic and technical evaluations.

Environmental Considerations -

The site appears excellent in consideration of the environmental aspects of aesthetics, odors, sanitation, and noise. The only problem was odors from pens in hot weather.

Results

The results are presented as the advantages and disadvantages of the Sacramento site refuse collection system in economics, effectiveness, efficiency, and environmental effects.

Economic Advantages -

The site is economical at $11.34 per capita per year and favorably compares with the $12.08 national average. The costs are:

- $14,486 per year for the site
- $24.10 per dwelling unit per year
- $11.34 per capita per year
- $2.63 per cu yd

Capital costs are minimal for the refuse system and compare favorably with the national averages.

Economic Disadvantages -

The operation and maintenance costs are high at $13,532 per year. The cost of collection and disposal of refuse represents $10,344 or 71 percent of the total annual costs. Estimates of elements of the city charges and observed site labor utilization show that labor is $6,759 (47 percent) and that landfill fees are $4,655 (32 percent)of the total annual costs.

Effectiveness, Advantages -

Refuse is effectively collected and disposed. Very little handling of refuse is required. Once a week backyard servise appears very effective for the site. Resident acceptance of the system appears excellent.

Effectiveness, Disadvantages -

Some of the refuse pens are overloaded possibly due to the pen location. Additional pens and trash cans or more frequent servicing might solve the problem.

Efficiency, Advantages -

Though considerable walking time is required, non-productive time does not occur; therefore, personnel utilization is excellent. The refuse collected per unit time and per man-hour is 0.1 cu yd per minute of elapsed time and 0.1 cu yd per man-minute. The refuse collected per mile driven is 3.2 cu yd per mile.

Efficiency, Disadvantages

Backyard collection requires considerable walking. Refuse collectors walk 56,183 feet per year to collect the refuse. The refuse collected per foot walked is about 0.1 cu yd per foot. The effectiveness and efficiency of collection in terms of cost are high, but the volume of refuse collected per unit of time appears low which is due to the backyard collection activities required to service 295 dwelling units.

Environmental Considerations, Advantages -

Site aesthetics are excellent. Noise associated with collection activities is minimal. In general, very few odors occur. Very little refuse handling is required. Littering is minimal. There are no sanitation problems.

Environmental Considerations, Disadvantages -

Odors occur in hot weather from overloaded pens.

KING COUNTY, WASHINGTON

The King County site was visited on April 14, 15, and 16, 1975, for the collection of technical and economic data for analysis of the refuse management system. In addition, a study of trash can collection versus plastic bag collection was conducted at the site from April 17 through May 14. The conduct and results of that study are presented in the following section of this report.

The refuse management system consists of once a week curbside pickup for SFA and SFD units and once a week container pickup for MFLR units. The pickup service is provided by resident contract with a private service contractor or the resident disposes refuse at a county transfer station. The refuse system is depicted in Figures 43 through 46. The site arrangement is shown in Figure 47. The site demographic and other data are given in Table 37.

FIGURE 43. Refuse (trash) cans set curbside by residents of SFD units at the King County Operation Breakthrough site.

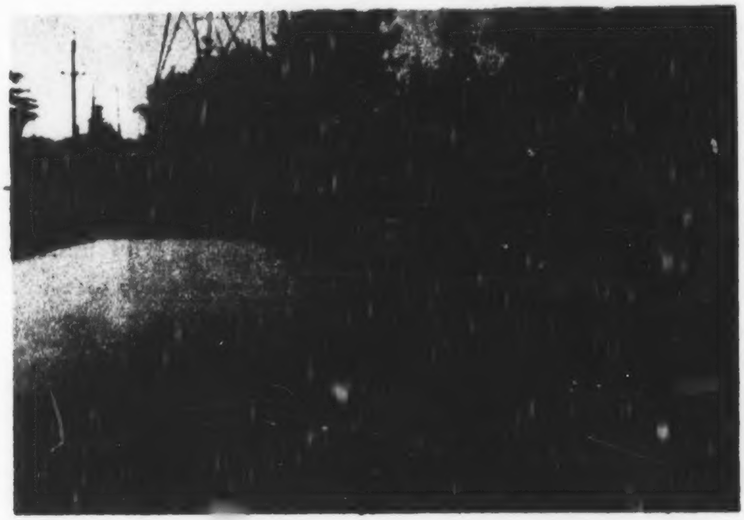


FIGURE 44. Refuse (trash) cans left curbside behind SFA units at the King County Operation Breakthrough site.

FIGURE 45. Typical of three two-cu yd containers used by MFLR residents at the King County Operation Breakthrough site.

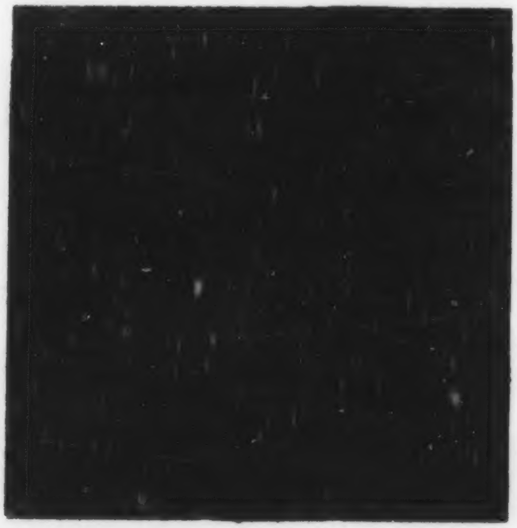


FIGURE 46. Refuse collection crew and 25-cu yd packer truck at the King County Operation Breakthrough site.

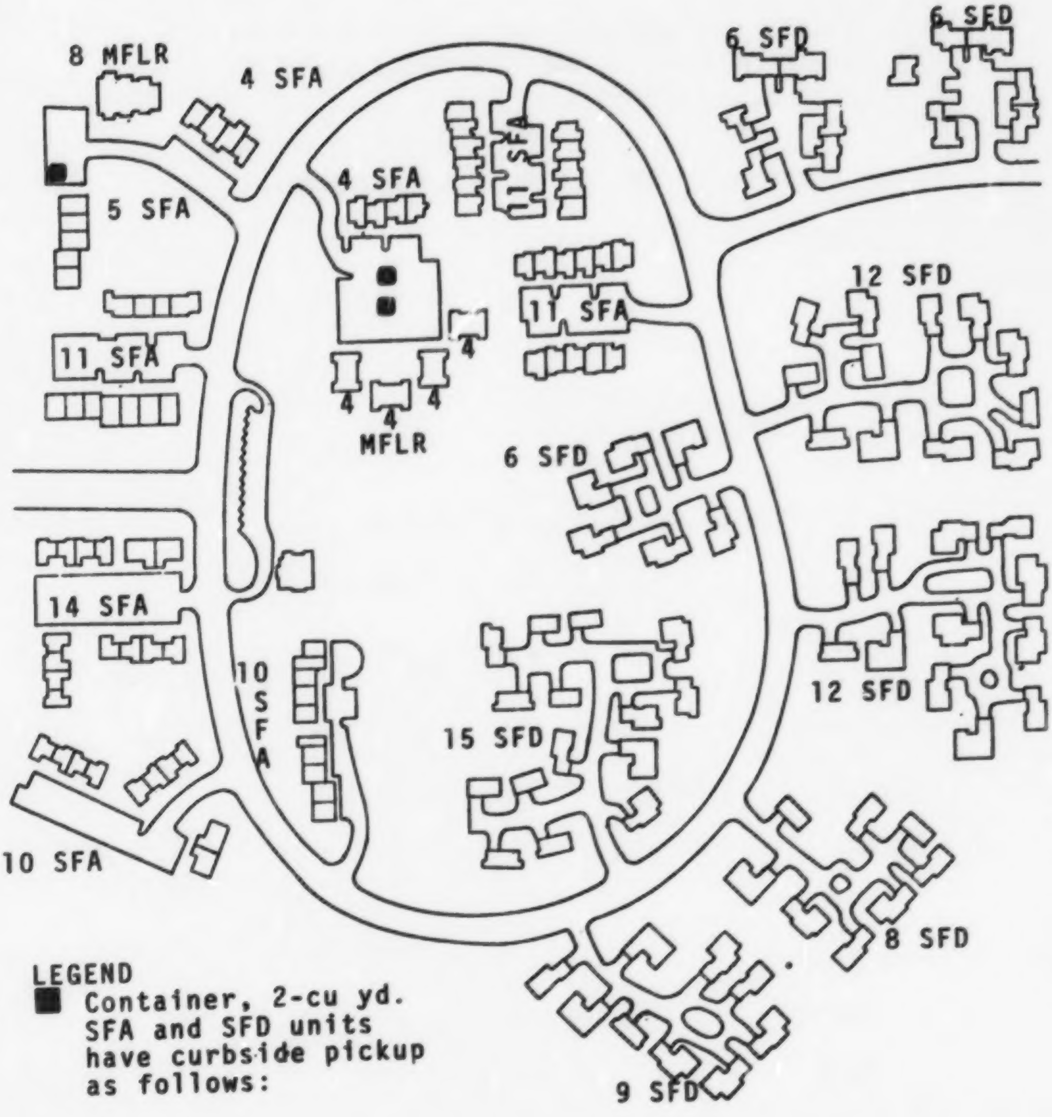

8 MFLR
4 SFA
6 SFD
6 SFD
4 SFA
SFA
5 SFA
12 SFD
11 SFA
4
11 SFA
4
4
4
MFLR
6 SFD
14 SFA
10
S
F
A
12 SFD
15 SFD
10 SFA
8 SFD
9 SFD
LEGEND
■ Container, 2-cu yd.
SFA and SFD units
have curbside pickup
as follows:

FIGURE 47. King County Operation Breakthrough site arrangement.

Table 37. DEMOGRAPHIC AND SOLID WASTE SYSTEM DESCRIPTIVE DATA FOR THE KING COUNTY OPERATION BREAKTHROUGH SITE

Number and type of dwelling units and occupancy:

Type	No.	Vacancies	Residents (estimated)
SFA	80	0	327
SFD	74	1	304
MFLR	24	0	68

Number occupied:	177 units
Number residents:	699 people
Site area:	35.9 acres

Distribution of units by type of service:

Units	People (estimated)	Type of Service
118-SFA/SFD	487 people	Curbside subscriber service - by private contracts, once a week
35-SFA/SFD	114 people	Haul their own refuse away
1-SFD	Vacant	-
24-MFLR	68 people	Use three two-cu yd containers, group service by private contractors, once a week

Average number of units per service:

SFA/SFD	1 unit per service
MFLR	8 units per service

Refuse System Description

Residents of the SFA and SFD dwelling units place refuse in trash cans which are set curbside. Residents of the MFLR units place refuse in three two-cu yd containers which are located in the parking areas adjacent to the units. The cans and containers are serviced once a week by a private contractor. The service is contracted by each SFA and SFD homeowner. Thirty-five SFA and SFD homeowners do not participate, and they dispose refuse at the county transfer station. The MFLR residents pay for the container service as a group. One SFD unit was vacant and no service was provided.

A crew of two men from the private service contractor collects refuse in a 25-cu yd packer truck on a once a week basis. The two-cu yd containers are equipped to be emptied by the same truck. Refuse is collected by the contractor on the basis of two cans emptied once a week. Bags may be substituted but the bag or can size must average about 32 gallons and be placed within 25 feet of the curb. The truck services other residential areas before and after servicing the site. Refuse is dumped at a county provided transfer station.

Economic Analysis

The economic data are given in Table 38 in general form. The private service contractor accounts for 44 percent of the costs to the site. The costs of various elements making up the price of the service contractor may be estimated from data obtained from discussions with the service contractor and from observations of refuse collection and disposal. The estimated costs of the private contractor service and individuals providing their own service is shown in Table 39. Eighty-five percent of the costs are for dump fees, labor and costs of automobiles used by individuals for disposal of refuse. If all residents subscribed to the private contract service, the costs would be reduced to values shown in Table 40. The site costs are $13.65 per capita per year compared with an adjusted national average of $12.08 per capita per year.

Technical Analysis

The private contractor services the site once a week with a 25-cu yd packer truck and a two-man crew. Other residential areas are serviced before and after the site is serviced. When full, the truck is emptied at a county transfer station.

Table 38. COST OF REFUSE COLLECTION AND DISPOSAL AT THE KING COUNTY OPERATION BREAKTHROUGH SITE

	Initial Costs	Multiplier[a]	Oct. 1975 Costs	Carrying Charge[b]	Annual Costs	Cost Per DU Per Yr (177)	Cost Per Cap. Per Yr (699)	Cost Per Cu Yd (2100 cu yd/yr)[c]
Capital Costs:								
Automobile[d]	$2,184	1.0000	$2,184	NA	$2,184			
Trash cans[e]	2,420	1.0618	2,570	0.146	375			
					$2,559	$14.46	$ 3.66	$ 1.22
Recurring Costs:	$ 0	-	$ 0	NA	$ 0	$ 0	$ 0	$ 0
Operating and Maintenance Costs:								
Automobiles[d]	$1,092	1.0000	$1,092	NA	$1,092			
Landfill fees[g]	1,586	1.0618	1,684	NA	1,684			
Refuse service[f]	3,960	1.0618	4,205	NA	4,205			
					$6,981	$39.44	$ 9.99	$ 3.32
Total Annual Costs:					$9,540 per yr	$53.90 per DU per yr	$13.65 per Capita per yr	$ 4.54 per cu yd

---

a - The multipliers used to adjust costs to an October 1975 basis are discussed in Section I.

b - The carrying charge is interest plus sinking fund factor. See Section I for explanation.

c - Observed refuse was about 1695 cu yd per year from 142 contractor service subscribers. The observed quantity is multiplied by 177/142 to obtain estimate of total site refuse load.

d - Thirty-five units dispose own refuse. Round trip distance is about 12 miles with one trip per week. Capital costs estimated at $0.10 per mile, O&M costs estimated at $0.05 per mile.

e - Two per unit at $6.85 each with 10-year life.

f - $27.04 per two-cu yd container and $2.75 per residence for two cans, billed monthly, all containers and cans serviced once a week, 118 units.

g - Fees are $0.75 per sedan load and $1.00 per station wagon or pickup truck load. Assumed 18 at $0.75 and 17 at $1.00 each week.

Table 39. COMBINED SEGMENTS OF ANNUAL EXPENSES FOR REFUSE COLLECTION AND DISPOSAL AT THE KING COUNTY SITE

	Private	Site	Segment Total	Percent of Annual Total
Capital Costs:				
Truck	$ 445		$ 445	5%
Containers (3)	12		12	-
Automobiles		$2,184	2,184	23
Trash cans		375	375	4
	$ 457	$2,559	$3,016	32%
Recurring Costs:				
Licenses, Taxes, Insurance	$ 44		$ 44	1%
Sales Tax	487		$ 487	5
	$ 531		$ 531	6%
Operation and Maintenance Costs:				
Labor	$2,116		$2,116	22%
Fuels and Maintenance	5	$1,092	1,097	11
Landfill fees	1,096	1,684	2,780	29
	$3,217	$2,776	$5,993	62%
Totals:	$4,205	$5,335	$9,540	
Annual Total	$9,540			100%

Table 40. COSTS OF REFUSE COLLECTION AND DISPOSAL AT THE KING COUNTY SITE ASSUMING THAT ALL RESIDENTS SUBSCRIBE TO THE PRIVATE CONTRACT COLLECTION SERVICE

	Annual Costs	Cost Per DU Per Yr (177)	Cost Per Cap. Per yr (699)	Cost Per Cu Yd (2100 cu yd/yr)
Capital Costs:				
Trash cans	$ 375	$ 2.12	$0.54	$0.18
Recurring Costs:	0	0	0	0
Operating and Maintenance Costs:				
Refuse service	$6,203	$35.05	$8.87	$2.95
Total Annual Costs:	$6,578	$37.17	$9.41	$3.13

An estimated 33-cu yd of loose refuse are collected each week by the private contractor from 142 dwelling units at the site. The annual estimated load is 1700-cu yd of loose refuse for the 142 units. Assuming an equal load of 12-cu yd per year per dwelling unit for the forty-three non-subscribing units, the non-subscribing residents dispose of about 400-cu yd of refuse by hauling refuse to the county transfer station in personal automobiles. The collection of refuse by the private contractor was observed and the technical data collection and analysis are for the private contract service. Non-subscribers were not observed disposing their own refuse. The technical data for refuse collection and disposal are summarized in Table 41 including distance travelled, number of stops, dwelling units serviced, crew size, refuse collected, estimated volume, elapsed time, and labor time expenditures. Table 41 includes observed data of service to 142 dwelling units. The non-productive time is waiting and packing time and is five percent of the total man-time utilized in collection activities.

Equipment Performance -

The refuse system does not utilize site-owned equipment. The following comments are directed to the refuse system as observed more than to equipment.

Table 41. OBSERVED REFUSE COLLECTION ACTIVITIES AT THE KING COUNTY SITE FOR ONE PICKUP AND ONE YEAR WITH ANALYTICAL RESULTS

							Time Elements				
Service	Distance Travelled	No. of Stops	No. of Units	Crew Size	Item Collected	Estimated Volume	Elapsed	Riding	Walking/ Handling	Waiting/ Packing	Total Man-time
Private Contractor Service (one pickup per week):											
	Truck: 2.3 miles Walk: 25,825 ft.	17	142	2	100 trash cans 91 plastic bags 3 containers	32.6 cu yd	3340 seconds	575 man-seconds	5775 man-seconds	330 man-seconds	6680 man-seconds
Total per yr	Truck: 120 miles Walk: 254 miles	884	142	2	-	1700 cu yd	48 hours	8 man-hours	83 man-hours	5 man-hours	96 man-hours

Analytical Results

Average distance per stop: truck 0.1 miles per stop
walk 0.3 miles per stop
Average labor per stop: 6.5 man-minutes per stop
Average dwelling unit density per stop: 8.4 dwelling units per stop
Average labor per cu yd: 3.4 man-minutes per cu yd
Riding: 0.3 man-minutes per cu yd
Walking/Handling: 2.9 man-minutes per cu yd
Waiting/Packing: 0.2 man-minutes per cu yd

Suitability - Curbside once a week collection provides a very suitable refuse collection and disposal system. The thirty-five homeowners who dispose refuse on their own can only be a suitable arrangement if they can dispose refuse while away from home enroute to perform other necessary duties. The landfill fees actually prohibit the cost effectiveness of individual refuse disposal. With automobile costs, the individual approach accrues an estimated $11.63 per month per dwelling unit as compared to the $2.75 per month charge of the private service contractor.

Effectiveness - If all homeowners on the site subscribed to the private contractor service, the costs of refuse collection and disposal would be $3.13 per cu yd as compared to an estimated current cost of $4.54 per cu yd. The cost effectiveness of the current system is 55 percent:

$$\left[1 - \left(\frac{4.54-3.13}{3.13}\right)\right] \times 100 = 55 \text{ percent}$$

Under-utilization of the curbside pickup service causes a low effectiveness of the refuse system.

Resident Acceptance - Residents complain of lack of sufficient trash can storage volume for refuse. The refuse pickup contractor allows two average trash cans per week for the $2.75 ($2.92 adjusted to October 1975 basis) charge per month. A separate report[2] discusses the attitudes of residents at the King County site with respect to the refuse management system. The conclusions of the report indicate that 28 percent of the residents reported inadequate disposal services and facilities primarily due to trash can overloading, scattering of refuse by household pets, and odors. In addition the residents indicate a lack of responsiveness to complaints made to the private service contractor. Observations over the three-days at the site revealed none of the problems reported in the survey.

Site Appearance -

The site appearance could be improved if residents removed trash cans from curbside after refuse has been collected. Particularly in the SFA dwellings, residents have trash cans curbside at all times (see Figure 44). SFD unit residents remove trash cans from the curbs and store out of view. There was practically no littering as the result of the refuse system.

Environmental Considerations -

The trash cans left curbside detract from appearance and are subject to external problems with insects, odors, and animals; however, observations revealed no environmental problems. There is noise associated with refuse collection but the disturbance is minimized by limited time on-site only once a week. Odors and sanitation problems were not evident.

Results

The results are presented as the advantages and disadvantages of the King County site refuse collection system in economics, effectiveness, efficiency, and environmental aspects.

Economic Advantages -

The site as designed has only the costs of trash cans and collection service. The cost of refuse collection and disposal could be low at $3.13 per cu yd if all homeowners subscribed to the collection service. Also, if all subscribed, the refuse collection and disposal would compare favorably with the national average for the service.

Economic Disadvantages -

The observed site accrues $13.65 per capita per year which is greater than the national average of $12.08 per capita per year. The 35 homeowners who dispose of their own refuse create the high cost situation. Their reasoning for performing their own disposal is unknown.

Effectivneess, Advantages -

Refuse is effectively collected and disposed. If properly utilized, the cost effectiveness would be excellent.

Effectiveness, Disadvantages -

The system is only 55 percent cost effective because the system is not fully utilized.

Efficiency, Advantages -

The collection of refuse averages 3.4 man-minutes per cu yd of refuse. Personnel utilization is excellent with 95 percent of labor time spent in productive collection activities and 5 percent in non-productive activities.

Efficiency, Disadvantages -

The only disadvantage with respect to efficiency is the disposal of refuse by some residents who do not subscribe to the private collection service.

Environmental Considerations -

Advantages - Odors are minimal. There are no sanitation problems. Noise is minimal. There is very little littering.

Disadvantages - Refuse cans are left curbside behind most SFA units; consequently, the aesthetics are not as good as possible. Some odors occur at the 2-cu yd containers in hot weather.

KING COUNTY PLASTIC BAG STUDY

The King County site SFA and SFD dwelling units were divided into two sections for a study of the curbside collection of trash cans versus plastic bags. Half of the dwelling units were furnished plastic bags for residents to line trash cans and set the filled bags curbside on collection day. The residents of the other half of the dwelling units used their trash cans in the normal manner. The site was observed from April 14 through May 14. Detailed time and motion recordings were conducted during refuse collection on April 23, May 7, and May 14. Figures 48 through 51 show bagged refuse set curbside awaiting pickup. Figure 52 shows the site arrangement and indicates the areas using plastic bags and trash cans. The results are given as a comparison between the halves of the site with respect to economics, collection efficiency, site appearance, user preference, and the environmental considerations of odors, noise, sanitation, and aesthetics.

Economic Comparison

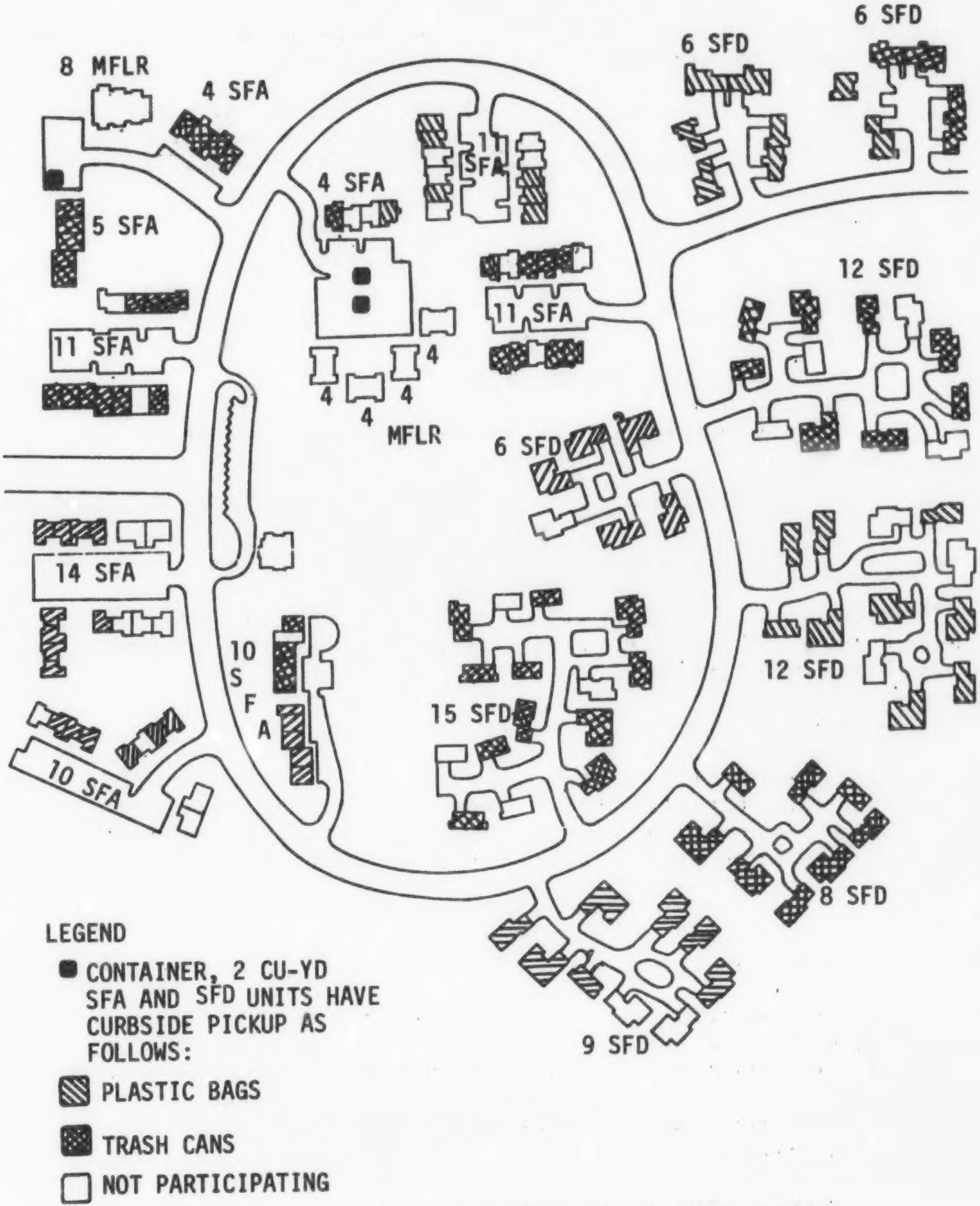
The only economic difference between the two halves of the site is the use of plastic bags. During the study period an average of 94 plastic bags were used each week by 61 participating homeowners. Three-mil thick, 32-gallon bags with ties were furnished for use by the residents. The bags retailed for $1.34 ($1.42 adjusted to October 1975 basis) for a box of eight in the King County area. A cost comparison on a per dwelling unit basis follows and assumes that the homeowner pays for the cost of the plastic bags and will only need one trash can. The homeowner using plastic bags

FIGURE 48. Bagged refuse set curbside for pickup, 122ND Court, King County, Washington

FIGURE 49. Bagged refuse set curbside for pickup, 122ND Court, King County, Washington

FIGURE 50. Bagged refuse set curbside for pickup, NE 149th Place, King County, Washington

FIGURE 51. Bagged refuse set curbside for pickup, NE 150th Street, King County, Washington


8 MFLR
4 SFA
6 SFD
6 SFD
11 SFA
4 SFA
5 SFA
11 SFA
11 SFA
12 SFD
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4
4
MFLR
6 SFD
14 SFA
10 S F A
12 SFD
15 SFD
10 SFA
8 SFD
9 SFD
LEGEND
● CONTAINER, 2 CU-YD
SFA AND SFD UNITS HAVE CURBSIDE PICKUP AS FOLLOWS:
▧ PLASTIC BAGS
▩ TRASH CANS
☐ NOT PARTICIPATING

FIGURE 52. Site arrangement showing units participating in the plastic bag versus trash can study at the King County site.

at the King County site pays an average of $17.41 per year more than the homeowners using trash cans.

	57 Homes Using Trash Cans (Per Dwelling Unit)	61 Homes Using Plastic Bags (Per Dwelling Unit)
Capital Costs:		
Cans	$ 2.10 per year	$ 1.05 per year
Recurring Costs:	0	0
Operating and Maintenance Costs:		
Plastic Bags	--	$18.46 per year
Private Contract	$35.04 per year	$35.04 per year
Total Annual Costs:	$37.14 per DU/yr	$54.55 per DU/yr

Technical Comparison

The technical comparison between plastic bags and trash cans considers efficiency, site appearance, user preference, and environmental effects.

Efficiency -

The data were collected by observing refuse collection from April 14 to May 14, 1975. The results are presented in Table 42. The results are compared for efficiency of service on the basis of several calculations:

	Plastic Bags	Trash Cans
Average elapsed time per stop	1.5 minutes per stop	3.2 minutes per stop
Average distance between stops	469 feet per stop	283 feet per stop
Average labor per stop	3.0 man-minutes per stop	3.3 man-minutes per stop
Average dwelling unit density	4.4 units per stop	3.4 units per stop
Average labor per item collected	0.4 man-minutes per bag	0.6 man-minutes per can
Average labor per cu yd of refuse	2.9 man-minutes per cu yd	4.4 man-minutes per cu yd
Riding:	0.8 man-minutes per cu yd	0.9 man-minutes per cu yd
Walking/Handling:	2.0 man-minutes per cu yd	3.0 man-minutes per cu yd
Waiting/Packing:	0.1 man-minutes per cu yd	0.5 man-minutes per cu yd

Table 42. RESULTS FROM OBSERVATIONS OF PLASTIC BAG VERSUS TRASH CAN PICKUP AT THE KING COUNTY SITE

						Time Elements				
Date	No. Stops[a]	Travel Distance	Units Served	Items Collected	Estimated Volume	Elapsed (sec.)	Riding	Handling/ Walking	Waiting/ Packing	Total
							(man-seconds)			
Plastic Bag areas of site:										
4-23-75	7	5,456 ft	47	80	11 cu yd	965	250	1,590	90	1,930
5- 7-75	14	5,248 ft	52	92	12	1,065	773	1,357	0	2,130
5-14-75	8	3,011 ft	29	53	7	555	419	691	0	1,110
Total:	29	13,615 ft	128	225	30 cu yd	2,585	1,442	3,638	90	5,170
Average:	9.7 per wk	4,538 ft/wk	43/wk	75/wk	10 cu yd/wk	862/wk	480/wk	1213/wk	30/wk	1723/wk
Per cu yd of refuse:	0.97/cu yd	454 ft/cu yd	4.3/cu yd	7.5/cu yd	-	86 sec/cu yd	48/cu yd	121/cu yd	3/cu yd	172/cu yd
Trash Can areas of site:										
4-23-75	7	4,900 ft	59	88	14 cu yd	1,723	600	2,556	655	3,811
5- 7-75	22	4,664 ft	58	90	13	1,715	724	2,336	370	3,430
5-14-75	23	5,159 ft	58	96	13	1,740	780	2,183	177	3,140
Total:	52	14,723 ft	175	274	40 cu yd	5,178	2,104	7,075	1,202	10,381
Average:	17.3 per wk	4,908 ft/wk	58/wk	91/wk	13 cu yd/wk	1,726/wk	701/wk	2,358/wk	401/wk	3,460/wk
Per cu yd of refuse:	1.7/cu yd	378 ft/cu yd	4.5/cu yd	7/cu yd	-	133 sec/cu yd	54/cu yd	181/cu yd	31/cu yd	266/cu yd

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[a] Some data were censored because residents used cans instead of bags or bags instead of cans.

The results favor the use of the plastic bags in all respects. A statistical comparison of items collected per unit time and per man-minute was conducted to insure that the data sample was sufficient to show significant difference between the results. Figure 53 illustrates the observed total elapsed time per item collected. Figure 54 illustrates the observed total man-time per item collected. At the 0.05 level of significance, the means are significantly different; therefore, the observed data was sufficient in quantity to distinguish the differences between the total times of refuse collectione either by cans or bags. The time expended in performing various collection activities are depicted in Figure 55 for collection of cans and plastic bags. The average times show that considerable labor savings result when using plastic bags. The handling and walking time are 9.6 man-seconds per item lower and the waiting and packing time is 4.0 man-seconds per item lower for plastic bags than for trash cans resulting in a total of 13.6 man-seconds per item saving or a 35 percent reduction in labor requirements per item collected excluding riding time. The reduction in labor per unit of refuse volume is 1.4 man-minutes per cu yd (31 percent) less for bags than for cans excluding riding time.

The labor utilization efficiency is higher for the plastic bag collection than for the trash can collection. As shown in Figure 55, only 0.4 man-seconds per plastic bag is nonproductive as opposed to 4.4 man-seconds per can. This results from once-only handling of refuse in bags and the elimination of spreading the refuse into the loading chamber of the packer truck. Bags are picked up and placed into the chamber, and bags contain the refuse during packing operations. Also, several bags can be picked up at one time whereas cans require emptying one at a time and returning to curbside. When a tote can is used, the trash cans are emptied into the tote can. The tote can is carried to the truck and emptied; however, the refuse must be spread into the packer chamber to prevent overflow. Refuse collection in the plastic bag experiment resulted in 98 percent efficient utilization of labor for productive collection activities whereas collection of standard trash cans utilized labor at 85 percent efficiency. Collection of refuse in plastic bags resulted in less time per stop and longer distances between stops because more refuse could be handled on each trip to curbside by the crew at each stop. Thirty-one percent (2.9 vs. 4.4 man-minutes per cu yd) less labor was required per cu yd for curbside pickup of plastic bags than for trash cans.

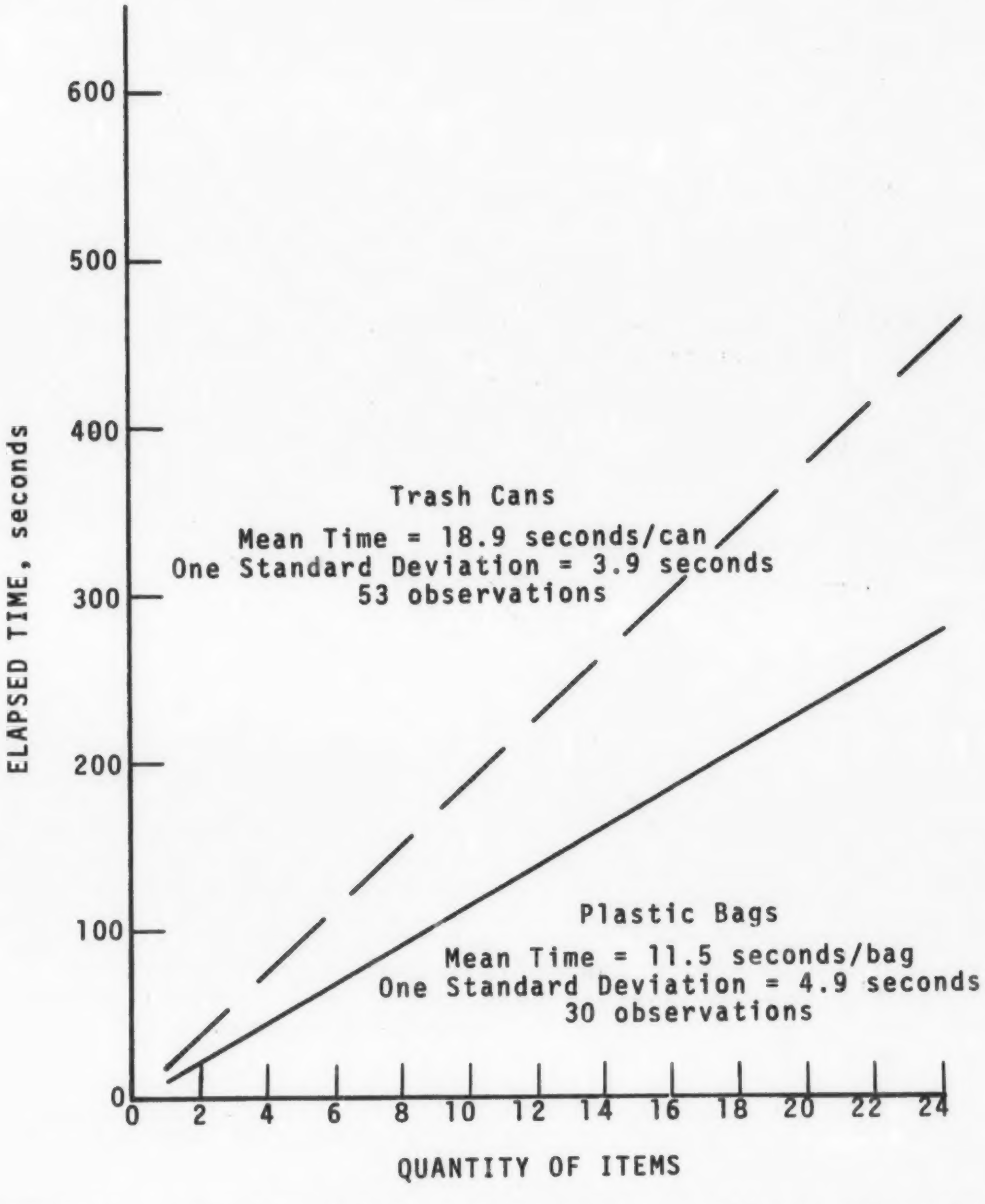

FIGURE 53. Observed total elapsed time to collect refuse in trash cans and plastic bags. Total time includes time spent riding, handling and walking, waiting, and packing.

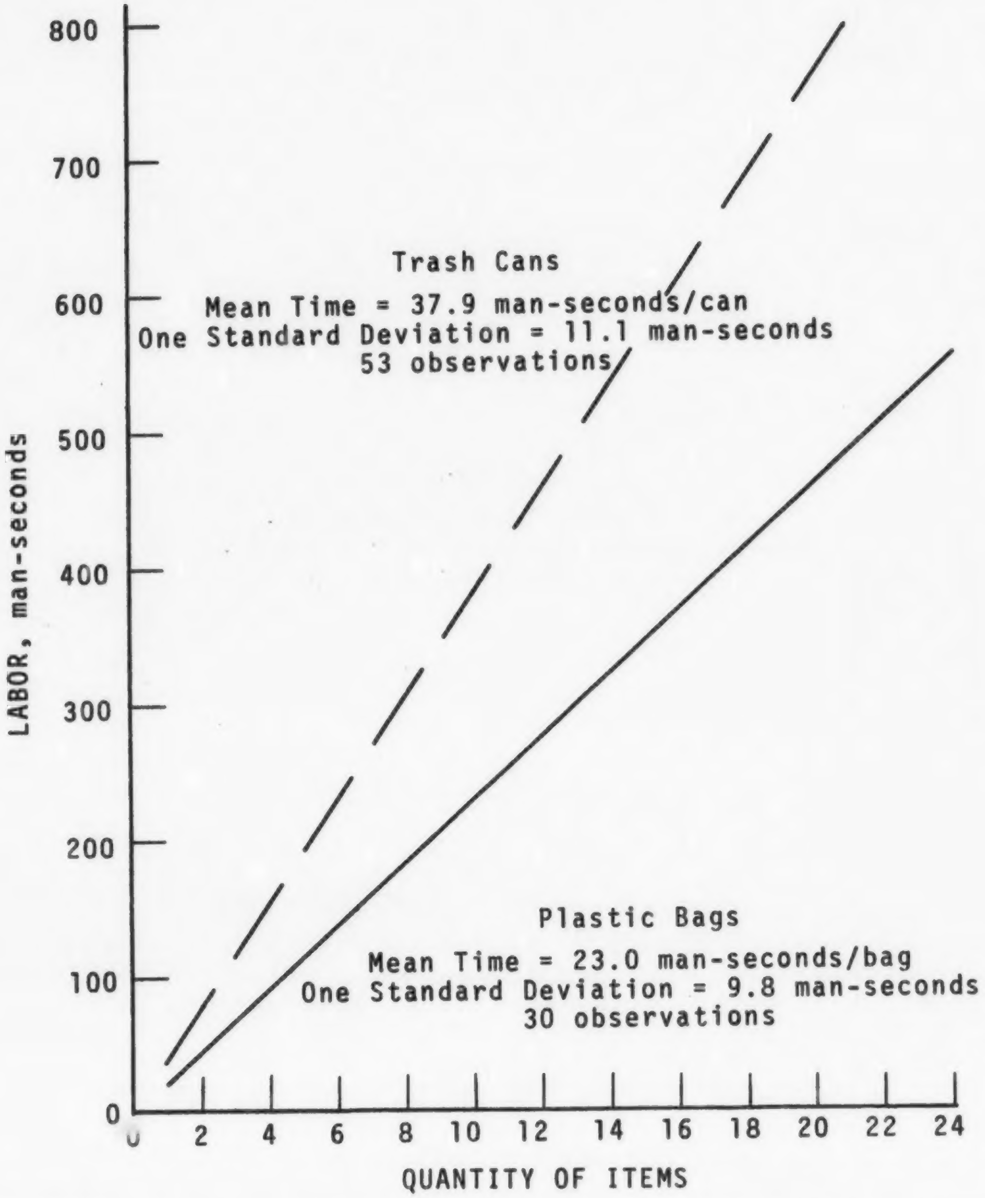

FIGURE 54. Observed total man-time to collect refuse in trash cans and plastic bags. Total man-time includes time spent riding, handling and walking, waiting, and packing.

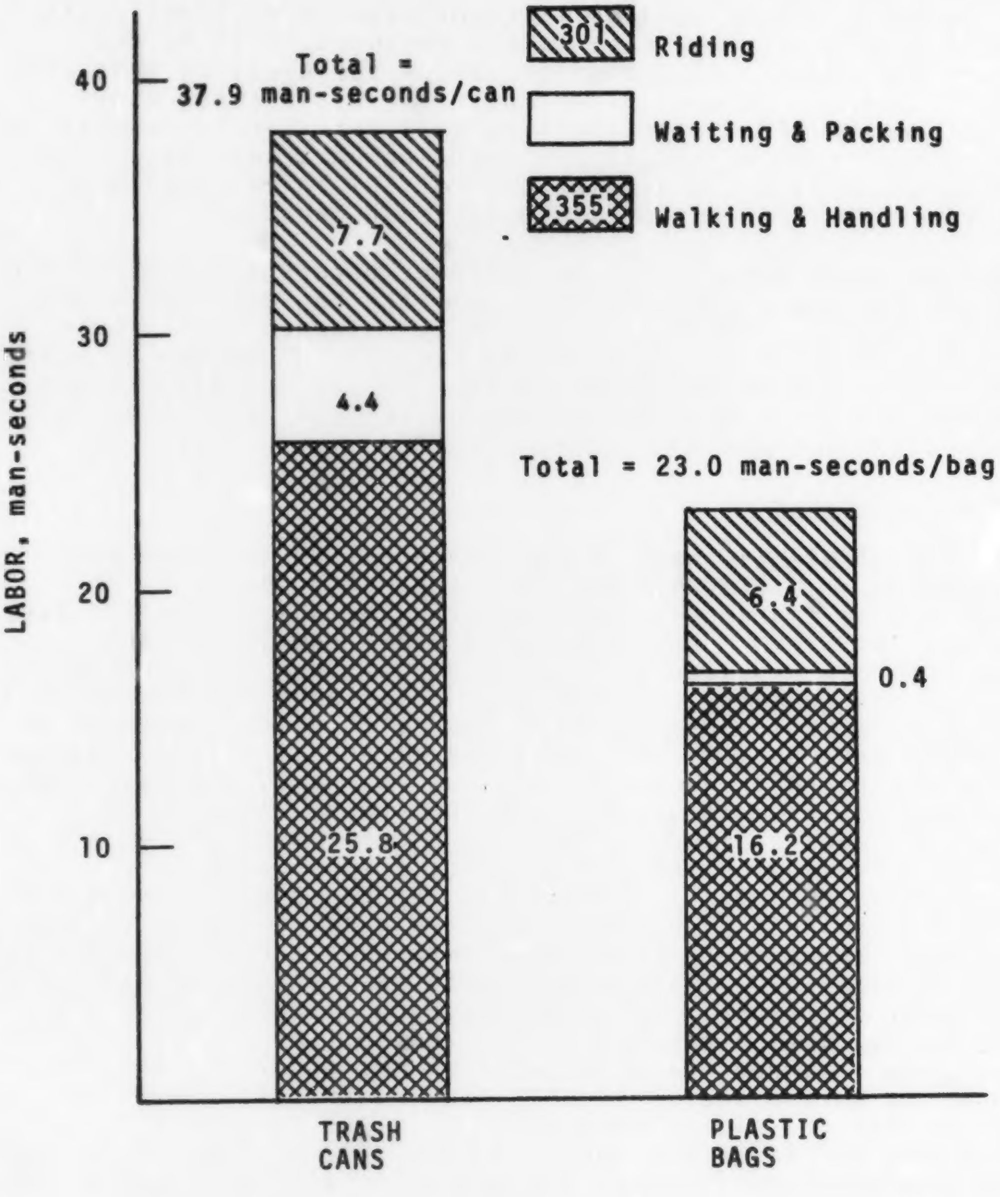

FIGURE 55. Average man-time spent on collection activities for trash cans and plastic bags.

If costs were reduced because of the labor reduction through the use of plastic bags, collection labor would be reduced 31 percent. This savings if translated to resident costs would result in a new cost to the resident of $2.47 per month for refuse collection or $29.64 per dwelling unit per year. Overall refuse system costs for plastic bag users would become $49.15 per dwelling unit per year as opposed to the actual cost of $54.55 per dwelling unit per year. The costs would still exceed the cost of $37.14 per dwelling unit per year for use of standard trash cans.

An additional benefit to the resident occurs through the use of plastic bags. The resident sets the bag curbside where it is picked up leaving no can to be returned to the home which is a particularly positive benefit to households where no one is home to retrieve the can. Also, the can, if used inside the home, does not become dented and desecrated by collection activities.

Site Appearance -

The use of plastic bags in the SFA areas of the site resulted in no difference to site appearance; however, a better site appearance resulted from the use of plastic bags in the SFD areas. Residents of the SFA housing have a concrete pad provided next to carports along the parking areas; consequently, the SFA residents leave trash cans curbside at all times whether lined with plastic bags or unlined. Residents of SFD homes keep trash cans inside garages or close to their homes; in all but one home, the cans were out of view from the outside of the home. The use of plastic bags resulted in trash cans being left out of view on pickup day with the plastic bags set curbside (see Figures 49 through 51). After pickup the plastic bag areas of the site were clean whereas trash cans were left curbside in those areas where trash cans were used during the test (see Figure 56). Plastic bags were very effective against spillage of refuse. Only one instance occurred where a pet had broken open a bag and strewn refuse (see Figure 57). The instance occurred the first week of the study and was not repeated during the subsequent four weeks. It should be noted that the pickup crew will not clean up strewn refuse as shown in Figure 57; the crew will only pickup the bag and the contents remaining in the bag. Overall, site appearance in SFD areas was improved by the use of plastic bags.

User Preference -

A survey of residents could not be performed; however, participation in the study plus casual conservation with residents indicated that the use of plastic bags was satisfactory

FIGURE 56. Photographs of trash cans left curbside after pickup.

FIGURE 57. Refuse spilled from a plastic bag as the result of being torn open by a pet.

even though most participants feared that pets would break into the bags and strew refuse. The collection crew definitely preferred plastic bags to trash cans because collection was faster not to mention the fact that the faster the time of collection the earlier the crew would complete the pickup route. As noted in the economic analysis, site pickup costs are not reduced by the service contractor if bags are used instead of cans. Pickup service management indicated that plastic bags become soft on hot days and tend to tear during the collection, particularly when the bag is exposed in the sun. The problem did not occur during the study possibly because 3-mil thick bags were used and because the site was serviced before nine thirty in the morning on each pickup day.

Environmental Effects -

The use of plastic bags with ties resulted in fewer odors, less noise, better aesthetics, and apparently less sanitation problems. The only problem which could be of an environmental concern is that plastic bags do not readily degrade in sanitary landfills as does loose refuse. Of particular interest is the reduction in noise levels because cans are not banged around during collection activities. Sanitation problems would appear to be lessened since the refuse is enclosed in bags and the collection crew is not exposed to the refuse.

Results

The use of plastic bags in place of standard trash cans results in $17.41 higher annual costs to the homeowner. Refuse collection activities are more efficient and require less labor when plastic bags are utilized. Refuse is collected faster when plastic bags are used. The collection crew prefers plastic bags because of increased pickup speed. The site appearance is improved because cans are not left curbside in the SFD areas after pickup of refuse. Site environmental conditions are as good or better when plastic bags are used. There is less collection noise when plastic bags are collected. Odors are minimized and there appears to be less possibility of sanitation problems when plastic bags are used. Overall, a site would appear to be improved if plastic bags are used in place of trash cans for curbside pickup; however, heavy duty bags (3-mil thickness) were used in the study and bags of less strength might have different results.

REFERENCES

(1) "1968 National Survey of Community Solid Wastes Practices," an Interim Report, EPA, USPHS, Cincinnati, Ohio, 1968.

(2) "Survey of User Acceptance of the Solid Waste Removal Systems at Operation Breakthrough Sites," Hittman Associates, Inc., and Applied Management Sciences, Inc., HUD/EPA sponsored, Cincinnati, Ohio, unpublished.

(3) Solid Waste Management, Hagerty, D. Joseph, Joseph L. Pavoni, and John E. Heer, Jr., Van Nostrand Reinhold Company, New York, 1973, p. 16.

(4) "Construction Scoreboard," Engineering News Record, 195(18), October 30, 1975, p. 18.

(5) "Construction Scoreboard," Engineering News Record, 191(13), September 27, 1973, p. 23.

(6) "Construction Scoreboard," Engineering News Record, 195(12), September 25, 1975, p. 25.

(7) "Construction Scoreboard," Engineering News Record 191(17), October 25, 1973, p. 28.

(8) "Construction Scoreborad," Engineering News Record, 193(5), July 25, 1974, p. 29.

(9) "Construction Scoreboard," Engineering News Record, 194(17), April 25, 1975, p. 18.

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